Summer 1985 11 $3

DEEP SKY

Summer's Billowy Nebulae
Measuring Double Stars
Well-Kept Secrets: Del, Sge, Vul

Letters to DSM

Galaxy Cluster Errata

Dave / During the weeks following my writing the galaxy clusters article for *Deep Sky* 10, several errors have come to light. In the discussion of NGC 4848 on page 9, column 3, the position angle given should be 160°, not 60°. This was a typo in my manuscript. Another error on the same page is where I refer to galaxy GMP 2976, which instead should be GMP 2946. (There is no GMP 2976 in the table.) The morphological type for GMP 2393 should be S0, not Sm. This was due to a mistaken impression on my part after having looked at the Palomar *Sky Survey* print of this object. The photo on page 9 near the bottom edge, shows the object clearly (and its type!) — it is the close companion to spiral NGC 4911. Near the end of the table, the first part of the morphological types for GMP 2157 and GMP 2000 should be (R′), not (R^+). The (R′) symbol indicates that the spiral arms or arcs of the galaxy nearly close to form a pseudo-ring around the galaxy.

The big problem is with the positions for the Coma galaxies. As mentioned in the text, they were derived from x,y positions listed by Godwin, Metcalfe, and Peach. A few weeks ago, Harold Corwin of the University of Texas sent me a long list of positions he'd measured astrometrically on photographs. His compare well with those published by others, and have an absolute error of around 3 arcseconds in each coordinate. Comparison with mine, however, revealed a systematic problem with the derived positions. To correct the positions given in the Coma table, add 2s to the R.A., and subtract 6″ from the Dec. The shift is consistent across the field, suggesting an error in the origin (0,0) R.A. and Dec. given by Godwin, Metcalfe, and Peach in the article.

Brian Skiff
421 West Aspen
Flagstaff, AZ 86001

Galaxies in Eridanus

Dear Dave / I enjoyed reading the detailed descriptions of galaxies in Eridanus by the collaborative group in Arizona and Australia in *Deep Sky* 9. While observing bright galaxies with my 13.1-inch Odyssey 1, I always closely scrutinize the surrounding field for faint NGC, IC, or anonymous galaxies.

As an example, while observing NGC 1453, a bright elliptical galaxy discussed in the article, I was surprised to find a close trio of fainter galaxies approximately 10′ southwest. Checking the *Revised New General Catalogue* revealed that these galaxies are NGC 1441, NGC 1449, and NGC 1451. Of the three, NGC 1441 was the brightest and appeared moderately faint with a condensed core. It was elongated in an east-west direction and measured perhaps 1′ across. Both NGC 1449 and NGC 1451 were faint, nebulous knots just 30″ across.

The de Vaucouleurs' *Second Reference Catalogue of Bright Galaxies* (RC2) lists V magnitudes as 12.9 (NGC 1441), 13.5 (NGC 1449), and 13.3 (NGC 1451), and mean surface brightnesses of 13.7 (NGC 1441), 14.0 (NGC 1449), and 12.7 (NGC 1451). *Deep Sky* readers who enjoy viewing galaxies in groups may want to investigate this trio next fall or winter when it will again be well-placed for viewing.

Steve Gottlieb
155 San Carlos
El Cerrito, CA 94530

Barnard's Loop Spotted

Dear Sir / I want to report a successful observation of Barnard's Loop using my 6-inch f/4 telescope and a nebula filter. At 18x the Loop was a featureless brightening of the field just northeast of the reflection nebula M78. A kite-shaped asterism of faint stars marked the boundary between nebulosity and dark sky.

That evening was a night of exceptional transparency, a front having just passed through (which often happens in Oregon!). To give you an idea of just how transparent the sky was, the Horsehead Nebula was easily spotted with averted vision in the 6-inch using an Hβ filter, and naked-eye seventh-magnitude stars were spotted in the Pleiades!

I really enjoy your magazine. I always wait by the mailbox when it's time for *Deep Sky* to come.

Mel Bartels
5064 E Street
Springfield, OR 97478

Baade 1 Bewilderment

Dear Mr. Eicher / During the past few years, members of the Saguaro Astronomy Club in Phoenix have attempted to find the difficult planetary nebula Baade 1, which lies at 3h53.5m, +19°28′ (2000) in Taurus. Its large size on *Sky Atlas 2000.0* suggests that it should be visible, but we've never found it. It is listed at photographic magnitude 13.9 and 40″ in diameter, so theoretically it shouldn't be too difficult to find. Has anyone ever spotted Baade 1 visually? Could you please publish a photograph of it to aid as a finder chart?

Chris Schur
HCR Box 952
Black Canyon City, AZ 85324

Chris / I've never observed this nebula, and know of no one who has. If that isn't enough, I don't even have a photograph of it! (Hint, hint, photographers!) Presumably, Baade 1's surface brightness is very low since its 14th magnitude light is spread out over more than half an arcminute. Its central star shines slightly brighter than 17th magnitude, and it lies 2.2 kiloparsecs away. Baade 1 is also known as Perek-Kohoutek 171-25.1 and is ring-like in structure. Can somebody with a really big scope look at this nebula come fall or winter? — DJE

Satisfaction . . . at Last!

Dear Dave / After 30 years of observing I have finally sighted the Flaming Star Nebula in Auriga, known formally as IC 405. I first learned of this beautiful object when it was featured in the January 1955 issue of *Sky and Telescope*. Not until recently did I have deep-sky filters which can make such dim objects visible. Neither *Burnham's Celestial Handbook* nor the Webb Society's *Deep Sky Observer's Handbook* list IC 405 as being observable. But with my 5-inch f/4.7 reflector at 21x and a Lumicon Hβ filter, IC 405 was visible as a dim double patch of light near two stars. The illuminating star, AE Aurigae, is a very hot "runaway star" which formed in Orion and has a rapid proper motion across the sky. The star is passing through a gas cloud which reflects its light. AE Aurigae will eventually pass through the cloud and the nebula will cease to shine.

Gus E. Johnson
RD 2, Box 67
Swanton, MD 21561

Variable Stars in M4

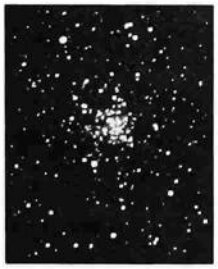
Dear Dave / *Deep Sky* readers with access to 10-inch and larger telescopes might be interested in following the rapid fluctuations of RR Lyrae variables in the loose globular cluster M4 (NGC 6121). These blue pulsating stars comprise more than 90 percent of all known globular cluster variables, but are normally much too faint to observe visually. Most have periods of about half a day, and a range of about one magnitude. M4 offers the best

DEEP SKY 11

The magazine for deep-sky observers and astrophotographers

Summer 1985
Volume 3, Number 2

Cover: M8, the Lagoon Nebula in Sagittarius, photographed by Alfred Lilge; 12.5-inch f/8 Ritchey-Chretien telescope, 098 film, 60-minute exposure from Palomar Mountain, California.



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6 Secrets of the Summer Sky

by Phil Harrington

Summer means warm weather and lots of observing, but most backyard telescopists spend too much time in too few places — primarily Cygnus, Sagittarius, and Scorpius. Although unspectacular to naked-eye viewers, the diminutive constellations Vulpecula, Sagitta, and Delphinus together offer 50 deep-sky objects which come alive when viewed with telescopes. Complete data for all objects appears in a table on page 10.

14 Stars in Need: Symbiotic Variables

by Dave Kratz

Among the most peculiar stars known are the so-called symbiotic variables — those normally showing a cool, M-type spectrum with absorption lines, but occasionally outbursting into a nova-like emission spectrum. This puzzling scenario led astronomer Paul Merrill to determine that symbiotic stars are composed of a cool red giant and a hot bluish subdwarf in close proximity. Unbeknownst to many observers, several of these stars are visible during summer nights.

20 Observing Small Nebulae, Part 2

by Chris Schur

The Winter 1984 issue of Deep Sky *contained an article on observing small nebulae scattered along the rich winter Milky Way. Arizona observer Chris Schur now concludes this two-part article by detailing the many small nebulae found along the summer Milky Way, which are marked on popular star atlases as "little green boxes." Complete data for 63 nebulae appear in a table on page 24.*

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opportunity to view these cluster variables, since at a distance of two kiloparsecs it is the nearest globular cluster to the Sun. It is also very loosely structured (Shapley Class IX). M4's only disadvantage is its low altitude for northern hemisphere observers (declination −26.5°).

In the September 1984 issue of the *Astrophysical Journal Supplement Series* (Volume 56, pages 19-65), Gonzalo Alcaino and William Liller present photographic photometry for over 1400 stars in M4, including many of the 40 RR Lyrae variables listed in 1973 by Helen Sawyer Hogg. Their paper includes several large scale "centerfold" finder charts, both for the bright central bar of stars and for the cluster as a whole. With these charts, it should be challenging but possible to follow at least 10 of the brightest variables, since their periods are quite short and accurately measured comparison stars abound nearby.

For example, the following four variables are all located within a 5′ circle just 5′ due north of the cluster's center:

Variable	Period	Mag. Range
6	7.7 h	13.5-14.1
7	12.0	13.0-14.3
15	10.7	13.0-14.3
19	11.2	12.8-14.2

Interested readers can purchase back copies of the *Astrophysical Journal Supplement Series* by writing to the Subscription Department, The University of Chicago Press, 5801 South Ellis Avenue, Chicago, IL 60637.

Jim Meketa
1029 Beacon Street
Newton Centre, MA 02159

Searching for SS-433

Dear Dave / Today my *Deep Sky 9* arrived. I enjoyed your article on exotic objects but was disappointed in the finder chart for SS-433. The position of SS-433 is not difficult to locate: a distinctive diamond-shaped asterism near the star appears in a Lick Observatory photo which ran in the October 1980 issue of *Scientific American*. At that time, I located SS-433 by luck after a 15-minute search of that general area of sky. SS-433 first appeared as a blur at low power, but was distinct when viewed at high power in my 14-inch Dobsonian. To find the bizarre object, locate the wide double shown on Tirion's *Sky Atlas 2000.0* at about 12h08m, +5°10. The diamond-shaped asterism lies southeast of these stars in the same 30′ field.

Bert Froehly
RR 2
Vandalia, IL 62471

Mr. Froehly / Thank you for the further explanation of how to find this difficult object. Also see the letters column in Deep Sky 10*, which contains a better photo of the region taken by Alexander Brownlee. — DJE*

ClusterMania

Dear Mr. Eicher / I am 15 years old and have been into deep-sky observing for a little over a year now. Several weeks ago a friend gave me *Deep Sky* issues 6, 8, and 9. After reading through them, I knew I had to have a subscription and immediately sent off a form.

I recently had my telescope out and saw 20 open clusters in about three hours of observing time — M35, M36, M37, M38, M41, M44, M45, M46, M47, M48, M67, M93, NGC 869, NGC 884, NGC 1980, NGC 1981, NGC 2360, NGC 2362, NGC 2423, and NGC 2539. It was a great thrill to see such a variety of clusters in one night. Some had bright stars while others had only faint stars. Some had hundreds of stars while others had only a few dozen. Some were large and others were compact. All of them were beautiful in their own way. Of all these clusters, only M46 in Puppis had a planetary nebula hidden amidst its numerous stars. The nebula is NGC 2438. It lies in the northern part of the cluster and has a magnitude of 11.3, making it easily visible in my 10-inch scope. I found M46 in my eyepiece at 36x and the nebula was invisible. At 72x, however, I could see it as a circular nebulosity with one star in its center. At 172x it appeared as a miniature Ring Nebula and was quite impressive.

David Russell
Rd #1, 22 Ithaca Road
Candor, NY 13743

Keep up the fine observing! — DJE

Man With the Big Eye

Dear Dave / You saw my 400mm telephoto lens fitted with a 2″ eyepiece at Stellafane this year. I use it for scanning around deep-sky objects and have had great success with it. Well, just last weekend I had a brainstorm. I attached it to my 50mm lens and came away with a 1.6x mini-scope with a huge exit pupil. Since the eye is indeed smaller, this reduces the effective aperture of the lens. Calculating backwards, a 7mm exit pupil gives an aperture of 10.9mm! Thus one gets a "bigger" eye at the small expense of some additional magnification. Then I added a UHC filter to the system — WHAM! — and got a supersensitive eye. I can't wait to try this on Barnard's Loop or the Helical Nebula!

Alister Ling
1865 St. Catherine W., #5
Montreal, Quebec, Canada, H3H 1M2

These photographs made by Ohioan Tom Eby were so nice we thought we'd publish them just to show you. At left is the galaxy NGC 2403, made with Eby's 8-inch f/5.6 SCT, hypered TP 2415, and a 43-minute exposure. At right is the distant globular cluster NGC 2419, made with the same system and film, exposure unknown. Thank you, Tom!

Inside View

A(nother) Discovery in

Back in February 1983, contributing editor Brian Skiff — along with Lowell Observatory astronomer Ted Bowell — discovered a comet. It was dubbed 1983c, Bowell-Skiff. In November 1984, Arizona observer David Levy, the writer who brings you *Variable Stars* and *Small Scope Showcase*, discovered a fuzzy moving object in Aquila. A day later, Massachusetts amateur Michael Rudenko spotted it too — 1984t, Comet Levy-Rudenko. For David, it was the climax of 17 years of searching for comets. (See the photo at right, made by John Glaspey and Rene Racine at the Mont Megantic Observatory in Quebec.) We're really proud of Levy and Skiff. Now, how about concentrating on discovering something a little farther away from the solar system . . ?

This issue contains a broad and unusual mix of things. Phil Harrington's lead article describes the varied and largely unknown deep-sky objects found in the constellations Delphinus, Sagitta,

the Family

and Vulpecula — little groups of stars bordering Cygnus and Aquila. Beyond M 27 — the favorite planetary for many observers — and the globular cluster M71, very few of these objects get observed. Why not venture out and attempt to find some of these little-known "secrets" of the summer sky?

The second article in this issue, written by SUNY's Dave Kratz, details symbiotic stars. These unusual cousins of planetary nebulae are rare and mystifying, having perplexed astrophysicists for years. Included in this article are identification sketches of several symbiotics as well as a table of the brightest such stars.

The final feature this month is the conclusion of a two-part article on observing small nebulae. (Part 1 appeared in *Deep Sky* 9.) In it, Chris Schur outlines the summer sky's best examples of small emission and reflection nebulae. These are not easy targets for most backyard telescopes and are indeed among the faintest objects anyone might look for with small scopes. To go after them, choose only a very dark night, maximize your dark adaptation and use of averted vision, and consider taking along a good nebula filter or two. Don't be discouraged if you don't find some of these during your first attempts — I've heard tales of dedicated deep-sky observers having first spotted the Cocoon Nebula after 35 years of looking for it!

Our review column this issue evaluates three products, one of which is an important reference book. Over the years, I've harped a bit in this magazine on the theme that most deep-sky reference books provide old, outdated information. Recently published by Cambridge University Press and Sky Publishing, *Sky Catalogue 2000.0, Volume 2* lists fundamental data for thousands of deep-sky objects. Its information is up to date and it's highly recommended. Also reviewed in this issue are Cambridge's *Colours of the Stars* and the Astronomical Society of the Pacific's new slide sets.

During the past, I've enjoyed

John P. Glaspey and Rene Racine

Comet Levy-Rudenko (1984t)

meeting with many of you at the usual summer meetings (Texas Star Party, Stellafane, etc.), but I won't be attending any this year because I have the opportunity to go on a special assignment in the fall. (More on that in the next issue.) I will welcome your letters this summer, though, whether you are a first-time correspondent or an old hand. I'll attempt to answer all that I can, and will use as much of your input as possible in the *Letters* column.

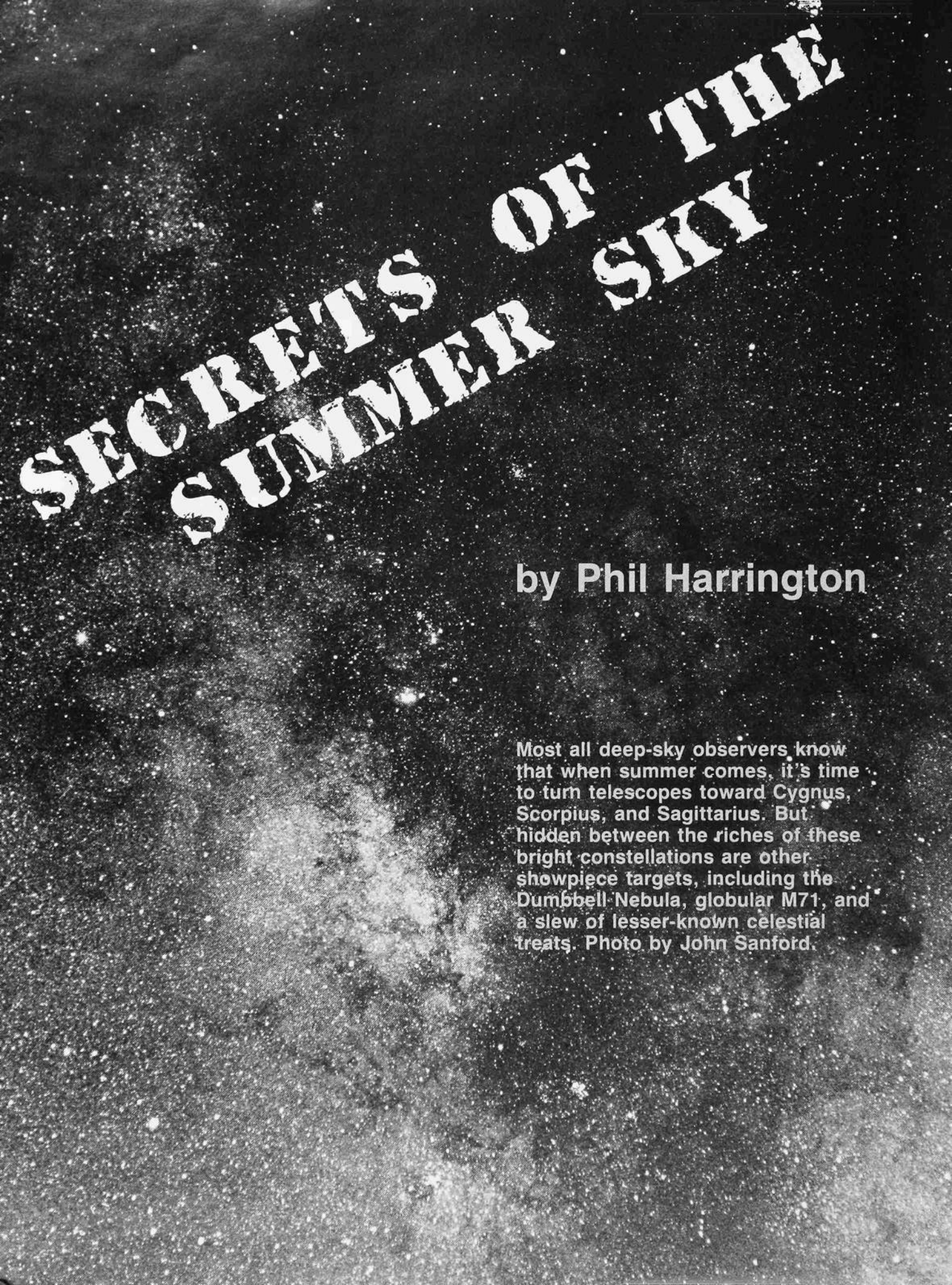
Yours truly,

Dave Eicher

Dave Eicher
Editor

SECRETS OF THE SUMMER SKY

by Phil Harrington



Most all deep-sky observers know that when summer comes, it's time to turn telescopes toward Cygnus, Scorpius, and Sagittarius. But hidden between the riches of these bright constellations are other showpiece targets, including the Dumbbell Nebula, globular M71, and a slew of lesser-known celestial treats. Photo by John Sanford.

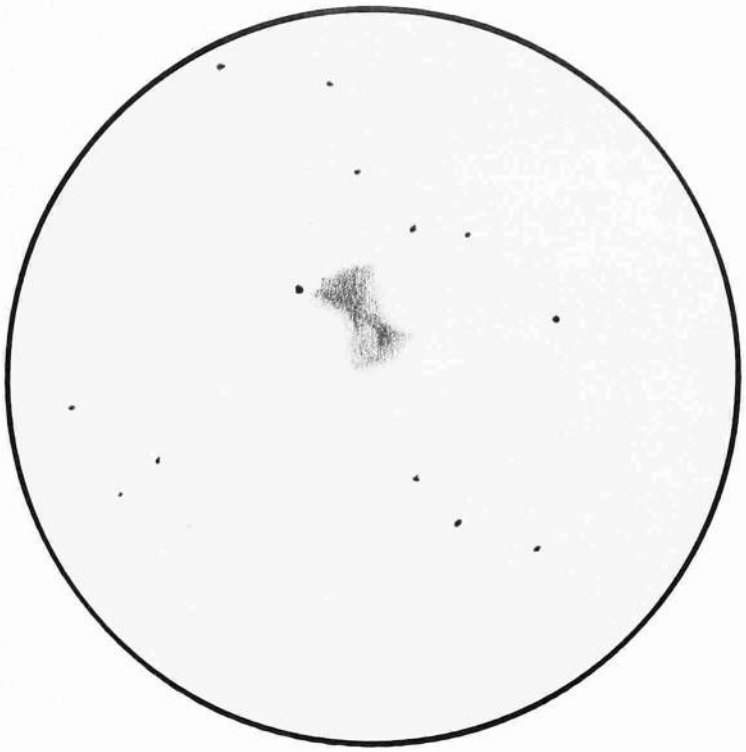
Summertime's back. At some point, when the night's crystal clear and you've run out of responsibilities, you'll step outside to gaze up at the darkening sky. Immediately attracting is Cygnus the Swan, rising from the east, which contains Deneb, one corner of the so-called Summer Triangle. You point binoculars at Deneb, bathed in twilight, and watch it twinkle. Memories of last summer stream back: the brilliant blue and yellow double Albireo, the large scattered cluster M39, the elusive North America Nebula, the bright planetary M27. WHAT? *M27, the Dumbbell Nebula, doesn't lie in Cygnus!* It is contained within **Vulpecula** the Fox. Vulpecula is just one of three inconspicuous constellations south of Cygnus which offer little to the unaided eye, but come alive when viewed with a telescope.

First, here's the lowdown on the three constellations. Lying directly south of Albireo and southwestern Cygnus, Vulpecula the Fox covers a mere 268 square degrees of sky — paltry compared with Cygnus' sky coverage of 804 square degrees. Vulpecula's brightest stars shine at only 4th magnitude, putting them near the lower limit of naked-eye visibility from suburban locations. Continuing southward through Vulpecula we find **Sagitta** the Arrow, which covers a mere 80 square degrees of sky. It contains one third magnitude star — Gamma (γ) Sagittae — and a handful of fourth magnitude stars. Directly south of central Cygnus is the small group of stars **Delphinus** the Dolphin, covering 189 square degrees and containing several third magnitude stars.

Vulpecula's Star Planetary and Rich Clusters

Vulpecula contains 24 reasonably bright deep-sky objects. Of these, the overwhelming favorite has to be **Messier 27** (NGC 6853), the beaming, bow tie-shaped planetary known as the Dumbbell Nebula. I am not going out on a limb by saying that this is the grandest planetary nebula in the sky, outclassing both NGC 7293 in Aquarius (which is brighter) and M57 in Lyra (which is more famous). Equal to a 7.3 magnitude star in brightness, the Dumbbell is clearly visible in 7x50 binoculars and most finderscopes as a hazy smudge just south of the star 14 Vulpeculae.

My 8-inch f/7 Newtonian reveals M27 as an hourglass-shaped cloud measuring about 10′x5′ across. It shines with a distinctive bluish hue, creating a stunning three-dimensional "floating" effect against a starry background. The last time out I was unable to spot the magnitude 12.0 central star — whose visibility is severely hampered by being surrounded by bright nebulosity — but under clear, dark skies and with ample magnification an 8-incher is capable of showing it. Under ideal conditions such a telescope shows over a dozen stars "involved" with the nebulosity, most of which are probably far in front of the Dumbbell itself.



One of the finest planetary nebulae lives in Vulpecula — M27, the Dumbbell Nebula. Phil Harrington made this sketch using his 8-inch f/7 reflector at 120x; it shows the Dumbbell's characteristic bowtie shape and the nebula's irregular brightness.

M27 is known to be one of the nearest planetary nebulae, lying at a distance of about 300 parsecs. (One parsec equals 3.26 light-years, which also equals about 29 trillion kilometers.) This correlates to an actual size for M27 of about ¾ of a parsec. Given these facts, and a measured expansion rate of approximately 27 kilometers per second, astronomers can calculate backward to arrive at an estimated age of 48,000 years. This is older than most planetaries by a factor of two. And given M27's high surface brightness, it will probably be around for a long time to come.

The southwestern corner of Vulpecula is home to a large, brilliant open cluster catalogued as **Collinder 399**. You may know it by its more popular names of Brocchi's Cluster, or the Coathanger. Visible to the unaided eye as a bright patch in the Milky Way, Collinder 399 contains the bright stars 4, 5, and 7 Vulpeculae. Since this cluster spans over 2°, binoculars give the best view of the dozen member stars. Telescopic fields of view are far too small to contain the entire group.

Just east of 7 Vulpeculae is the small, dense open cluster **NGC 6802**. Here about 60 stars, the brightest being magnitude 12.9, are gathered in an area measuring only 3.2′ across. A 6-inch telescope begins to resolve the brightest members of NGC 6802, but only the largest backyard telescopes show dozens of stars down to 15th magnitude or fainter. This group lies just under one kiloparsec away, and is an old cluster, having been around for 1.7 billion years.

Having just observed NGC 6802 with a polar-aligned telescope, now leave the scope pointing as it is, turn off the drive (if it has one), and take a nine-minute break. When you return, the nebula **IC 1305** should be in view. This object is visible as a faint diffuse cloud on the northwestern edge of a ninth magnitude star. My 8-inch scope does not show this nebula, but slightly larger backyard instruments should.

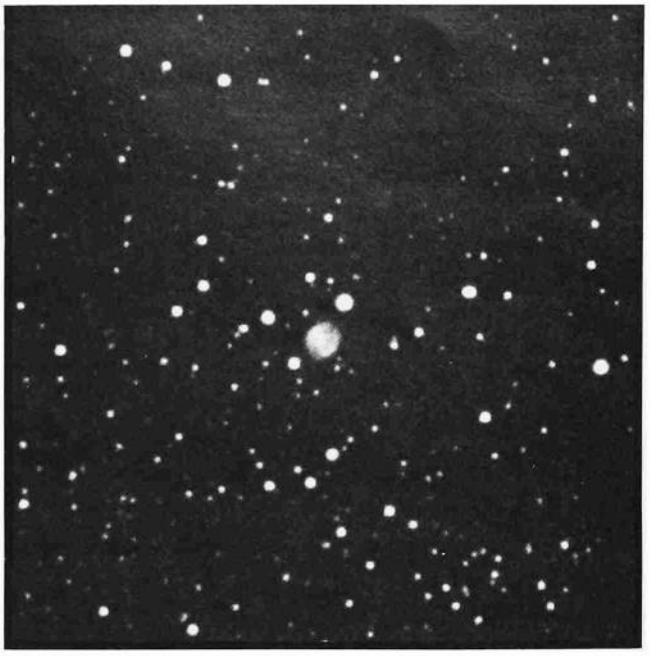
Look 30′ northwest of Alpha (α) Vulpeculae and you'll see the open cluster **NGC 6800**. Medium size telescopes show about 20 stars gathered in a 15′ field. The brightest cluster members are about 10th magnitude, and stand out nicely against the rich background. Just east of NGC 6800 is the little known open cluster **Stock 1**. To me, this simply looks like a rich field of stars. The field contains 40 stars fainter than 7th magnitude, but

they may not be physically associated in a cluster. Volume 3 of the Webb Society's *Deep Sky Observer's Handbook* gives a similar description. Stock 1 goes unmentioned in *Burnham's Celestial Handbook*, and is not plotted on any popular star atlas. What do you see here?

The small group of stars **NGC 6823** is easier to detect. This cluster is real, and contains about 30 stars of magnitude 8.8 and fainter in an area measuring 12′ across. Surrounding it is **NGC 6820**, a faint emission nebula spread over 40′x30′. The nebula has a very low surface brightness, making it very difficult to observe. A dark night, low-power field, and a UHC filter should bring it out, however, as a large milky patch of light. About 30′ north of 12 Vulpeculae is the open cluster **NGC 6830**. This is a small, rather poor group containing 20 stars spread out over 12′. The cluster's brightest star shines at magnitude 9.9, but most of its members are magnitude 10 to 12, and they may blend into a nebulous glow in small telescopes.

Halfway between Chi (χ) Cygni and 13 Vulpeculae is **NGC 6834**. Sharp-eyed observers may be able to glimpse this open cluster in 7x50 binoculars, although a 4-inch is needed to resolve the brighter stars. This rich cluster holds 50 stars in an area measuring only 5′ across, giving it an appearance like that of cosmic buckshot punched through a dark sky. NGC 6834's brightest star is a magnitude 9.7 object, and most of the remaining members shine at magnitudes 11 to 13. From this cluster, move four degrees south to find the attractive triple star **OΣ388**. This star's primary is an 8th magnitude object, as is the companion which lies at a distance of only 3.7″ (p.a. 139°). The third system member is a magnitude fainter and 31″ from the primary at p.a. 135°.

Looking for a challenge? Then try looking for **NGC 6842**, a faint planetary nebula about a degree east of NGC 6834. Use low magnification when searching for it, since the 13th magnitude disk is nearly 1′ across. Large telescope operators with keen eyes may catch a glimpse of the 16th magnitude central star. Once you've found NGC 6842, turn off your clock drive and let the stars drift through the field of view for 10 minutes. Then look



Opposite page: **The Dumbbell Nebula photographed by Ron Potter; 14-inch f/11 SCT, 30-minute exposure on hypersensitized TP 2415.** ***Above left:*** **The scattered open cluster NGC 6823 in Vulpecula covers 12′ of sky and lies nearly three kiloparsecs away. Photo by Martin C. Germano; 8-inch f/10 SCT, 75-minute exposure on 103a-F film.** ***Above right:*** **Visible in nearly any telescope, the planetary NGC 6905 shines at around 12th magnitude. Photo by Martin C. Germano; 8-inch f/10 SCT, 40-minute exposure on 103a-F film.** ***Right*****: Large, nearby NGC 6940 is one of the brightest deep-sky objects in Vulpecula. Photo by John A. Leoder; 8-inch f/10 SCT, 60-minute exposure on hypersensitized 103a-F emulsion.**

carefully, and maybe you'll see the tenuous reflection nebula **IC 4954/4955**. A nebula filter will undoubtedly aid in the detection of this small, very faint diffuse cloud. This complex is a difficult catch; if you successfully net this one, be sure to drop us a line.

Surrounding the 6th magnitude star 20 Vulpeculae is **NGC 6885**. Here my 8-inch reflector shows about 30 stars of magnitude 6 to 11 set within a 15′ field. The third volume of the Webb Society's *Deep Sky Observer's Handbook* notes that open cluster NGC 6882 is visible in the same eyepiece field. Although I was unable to see a second cluster, the handbook mentions that observer David A. Allen saw the two "6′ apart; the separation being somewhat arbitrary." Allen counted 15 stars in 6882 and 30 in 6885.. Can others discriminate between the two, which presumably coexist in a rich starfield?

The prettiest telescopic open cluster in Vulpecula has to be **NGC 6940**. Here you'll discover a tightly packed swarm of about 100 stars, all shining at magnitude 9 and fainter. Many attractive multiple stars can be found within. Of particular interest is **2698**. The 8th and 9th magnitude components are 4.4″ apart, with the secondary star at p.a. 302°. If you haven't already seen NGC 6940, be sure not to let the summer slip by without adding it to your list of clusters. And while in the neighborhood, try to find **Nova Vulpeculae 1984**. Discovered last December by Peter Collins, it flared to magnitude 5.7 around the first of the year. (That's the brightest nova since Nova Cygni 1975). It has faded steadily even since, but may still be visible in larger scopes.

Sagitta: Globulars and Galaxies

Sagitta the Arrow, one of the smallest summer constellations, has much more to offer than you might think. Its showpiece is **M71** (NGC 6838), a fabulous globular cluster with a very unusual appearance. It is a very rich, loose cluster, consisting of 12th magnitude and fainter stars. Since its discovery by J.G. Koehler in 1775, M71 has proven a difficult object to classify. It has been thought of as a sort-of transition object between open and globular clusters, due to its myriad stars arranged loosely. Debate raged over

The Summer Sky's Best-Kept Secrets

Type	Designation	R.A. (2000) Dec.	Con	Mag.	Mag.*	Spectrum	Size/Sep./Per.	P.A.	Distance	Linear Diameter
●	Palomar 10	19h18.2m +18°34′	Sge	—	—	—	3.5′	—	9.0:kpc	9pc
EV	U Sagittae	19h18.8m +19°37′	Sge	6.6–9.2	—	B8 III + K:	388d	—	180 pc	0.1 AU
⊙	Collinder 399	19h25.4m +20°11′	Vul	3.6	5.2	—	60′	—	130 pc	—
□R	van den Bergh 126	19h27.1m +22°43′	Vul	—	8.3	A2	7′ x 5′	—	—	—
⊙	NGC 6800	19h27.2m +25°08′	Vul	—	10p	A	—	—	—	
□ER	Sharpless 2-82	19h30.3m +18°16′	Sge	—	10.7	BO	7′	—	—	—
⊙	NGC 6802	19h30.6m +20°16′	Vul	8.8	12.9	B6	3.2′	—	1.0 kpc	—
⊙	Stock 1	19h35.8m +25°13′	Vul	5.3:	7.0:	AO	60′	—	—	—
□E	NGC 6813	19h40.4m +27°18′	Vul	—	—	—	3′	—	—	—
□E	NGC 6820	19h43.1m +23°17′	Vul	—	—	—	40′ x 30′	—	—	—
⊙	NGC 6823	19h43.1m +23°18′	Vul	7.1	8.8	07	12′	—	2.7:kpc	—
□E	Sharpless 2-88	19h46.0m +25°20′	Vul	—	—	B	18′ x 6′	—	—	—
□E	Sharpless 2-84	19h49.0m +18°24′	Sge	—	8.0	B5.5 V	15′ x 3′	—	—	—
□E	Sharpless 2-90	19h49.3m +26°52′	Vul	—	—	—	8′ x 3′	—	—	—
⊙	NGC 6830	19h51.0m +23°04′	Vul	7.9	9.9	BO	12′	—	1.5 kpc	—
⊙	Harvard 20	19h53.1m +18°20′	Sge	7.7	9.8	—	7′	—	—	—
●	M71 (NGC 6838)	19h53.8m +18°47′	Sge	8.3	—	G3	7.2′	—	4.0 kpc	9.0 pc
■	NGC 6842	19h55.0m +29°17′	Vul	13.6p	16.0	—	0.8′	—	—	—
■	M27 (NGC 6853)	19h59.6m +22°43′	Vul	7.3p	12.0	07	8.0′ x 5.8′	—	250 pc	0.6 pc
■	PK 60-4.1	20h00.2m +21°43′	Vul	16.6p	13.3	—	0.6′	—	—	—
□R	IC 4954/4955	20h04.8m +29°15′	Vul	—	—	—	25′	—	—	—
⊙	Roslund 4	20h04.9m +29°13′	Vul	10.0	11.6	—	—	—	—	—
IV	WZ Sagittae	20h07.6m +17°42′	Sge	7.0–15.5	—	P(Q)	Irr	—	—	—
■	NGC 6879	20h10.5m +16°55′	Sge	13.0p	15p	Of + WR?	0.1′	—	—	—
⊙	NGC 6882	20h11.7m +26°33′	Vul	8.1:	9.9	B5	18′	—	—	—
IV	FG Sagittae	20h11.9m +20°20′	Sge	9.5–13.7	—	B4 Ieq–F6 Iep	Irr	—	2.5 kpc	0.4 pc
⊙	NGC 6885	20h12.0m +26°29′	Vul	5.7p	6p	B5	7′	—	590 pc	—
■	NGC 6886	20h12.7m +19°59′	Sge	12.2p	15.7	Cont	0.1′	—	—	—
■	NGC 6891	20h15.2m +12°42′	Del	11.7p	12.4	07	0.2′	—	—	—
■	IC 4997	20h20.2m +16°45′	Sge	11.6p	13v?	Of + WR	0.1′	—	—	—
IV	V Sagittae	20h20.3m +21°06′	Sge	9.5–13.9	—	P	Irr	—	—	—
■	NGC 6905	20h22.4m +20°07′	Del	11.9p	13.5B	WC6	0.8′	—	—	—
SB(s)ab	NGC 6928	20h32.8m +09°56′	Del	12.6	—	—	2.2′ x 0.8′	—	65 Mpc	40 kpc
SB(s)ab?sp	NGC 6930	20h33.0m +09°52′	Del	13.1	—	—	1.4′ x 0.6′	—	60 Mpc	20 kpc
●	NGC 6934	20h34.2m +07°24′	Del	8.9	—	F7	5.9′	—	14.7 kpc	—
⊙	NGC 6940	20h34.6m +28°18′	Vul	6.3	9.3	B8	31′	—	800 pc	—
★²	Beta (β) Delphini	20h37.5m +14°36′	Del	4.0,4.9	—	F5	0.6′	346°(1974)	—	—
S0⁻:	NGC 6944	20h38.4m +07°00′	Del	13.3	—	—	1.7′ x 0.8′	—	60 Mpc	30 kpc
SBb	NGC 6956	20h44.0m +12°31′	Del	13.5p	—	—	2.1′ x 2.0′	—	—	—
Sab?	NGC 6954	20h44.1m +03°13′	Del	13.2	—	—	1.1′ x 0.6′	—	55 Mpc	20 kpc
★²	Gamma (γ) Delphini	20h46.7m +16°07′	Del	4.5,5.5	—	G5	9.6′	268°(1976)	30 pc	300 AU
S0/a	V Delphini	20h47.8m +19°20′	Del	8.1–16.0	—	M4e – M6e	533d	—	—	—
■	NGC 6972	20h50.0m +09°54′	Del	14.3p	—	—	1.4′ x 0.7′	—	3.0 kpc	—
■	PK 59-18.1	20h50.1m +13°33′	Del	14.6p	16.1	—	2.2′	—	—	—
Sdm	UGC 11651	20h57.3m +25°58′	Vul	14.2B	—	—	3.4′ x 1.0′	—	25 Mpc	25 kpc
●	NGC 7006	21h01.5m +16°11′	Del	10.6	—	F4	2.8′	—	34.7 kpc	30 pc
Sdm	UGC 11707	21h14.5m +26°44′	Vul	14.2B	—	—	3.6′ x 2.0′	—	15 Mpc	15 kpc
■	PK 72–17.1	21h16.8m +24°10′	Vul	12.2p	17.1	sdOp	13.9′	—	—	—
E4	NGC 7052	21h18.6m +26°27′	Vul	14.0p	—	—	2.8′ x 1.6′	—	70 Mpc	60 kpc
SB(r)b	NGC 7080	21h30.0m +26°43′	Vul	14.1p	—	—	2.0′ x 1.9′	—	70 Mpc	40 kpc

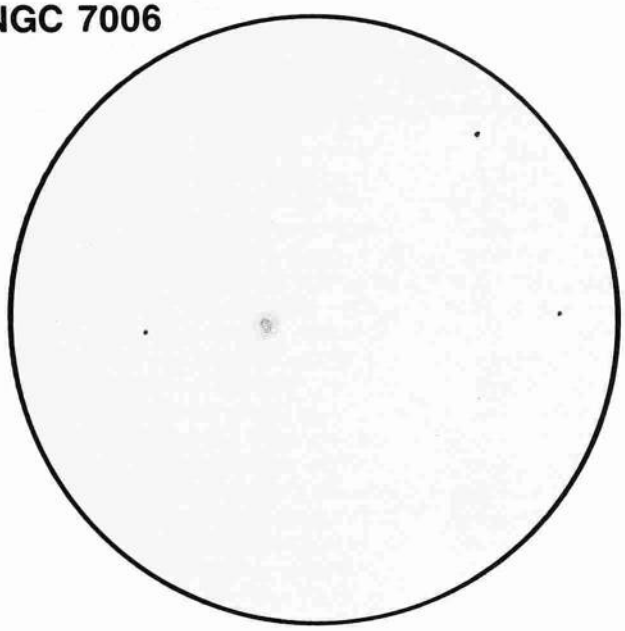
Column 1: Object type; ★² = double star, EV = eclipsing variable star, IV = irregular variable star, ⊙ = open star cluster, ● = globular star cluster, ■ = planetary nebula, □E = emission nebula, □R = reflection nebula, □ER = complex nebulosity, revised Hubble types given for galaxies. **Column 2:** Designation in *Revised New General Catalogue* by J. Sulentic and W. Tifft, *Index Catalogue* by J.L.E. Dreyer, *Yale Catalogue of Bright Stars* by D. Hoffleit, and additonal lists. **Column 3:** Corredinates for epoch 2000.0. **Column 4:** Constellation in which object lies. **Column 5:** Integrated magnitude in V system, unless B (= blue magnitude) or p (= photographic magnitude); (:) denotes uncertainty. **Column 6:** Integrated magnitude of central star for planetary nebulae or brightest star in open clusters. **Column 7:** Integrated spectrum. **Column 8:** Angular size in arcminutes or arcseconds, or period in days for variable stars, or angular separation for double stars. **Column 9:** Position angle for double stars, with year measured. **Column 10:** Distance in parsecs, kiloparsecs, or megaparsecs. **Column 11:** Linear diameter in parsecs or kiloparsecs, or separation between components in Astronomical Units for double stars. Data for open star clusters from B. Skiff, Lowell Observatory, and G. Lynga, *Catalogue of Open Cluster Data*, 3rd edition. Data for globular star clusters from G. Alcaino, *P.A.S.P.*, **89**:491, 1977. Data for galaxies from G. de Vaucouleurs, A. de Vaucouleurs, and H. Corwin, *Second Reference Catalogue of Bright Galaxies*, Univ. of Texas Press, 1976.

M71's nature until very recently, when it was well established that the gem of Sagitta indeed is a rich, unusual globular cluster. An 8-inch telescope well resolves M71's edges, leaving the center a granulated glow. A 12.5-inch reflector is able to more fully resolve it, when viewed with medium power. M71 is thought to be 4.0 kiloparsecs away, giving it a diameter of 8.4 parsecs. Just to the southwest of M71 is the open cluster **Harvard 20**, made up of about 20 dim suns. Positive identification can prove difficult, as the group is loosely gathered across 10', and is set against a fairly rich field.

Tucked inside the northeast corner of Sagitta, near 18 Sagittae, is **V Sagittae**, a unique variable star. Its classification is uncertain, although its behavior seemingly mimics that of U Geminorum-type stars. The brightness varies irregularly from magnitude 9.5 to 13.9. After an extensive study in 1964 at Lick Observatory, it is now thought that V Sagittae is an unusual binary system, consisting of a type WN5 star and a dG star. As the smaller WN5 component orbits the primary sun, it occasionally eclipses it and produces a minimum. Further variations are caused by the eruption of semi-opaque gases, which can cloud the entire system. As the haze clears, the star resumes shining at its full intensity. By following V Sagittae over a period of weeks or months, you can develop your own light curve demonstrating this dramatic chain of events. A chart showing suitable comparison stars is available from the American Association of Variable Star Observers (187 Concord Ave., Cambridge, MA 02138), or in volume 3, page 1532, of *Burnham's Celestial Handbook*.

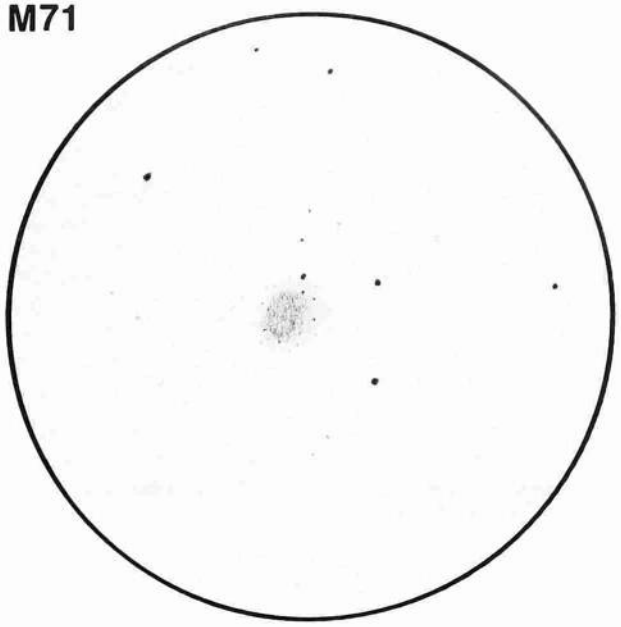
The stellar planetary nebula **NGC 6886** can be found southwest of V Sagittae. This object is easily mistaken for a star in all but high power. At 210x, my 8-inch scope shows a tiny oval disk, measuring about 5″x10″. Nearly identical in appearance is **NGC 6879**, located about three degrees farther south. Large apertures may display its 5″ disk, but there will be no sign of its central star. Riding on the Delphinus border is the planetary **IC 4997**. Its spans only 2″x1″, so don't expect to see much here. However, the central stars shines at 14th magnitude, so it should

NGC 7006



8-inch f/7 reflector
112x

M71



8-inch f/7 reflector
120x

Sketches by Phil Harrington

be possible in a 10-inch telescope. All three of these planetaries require excellent optics, superb seeing conditions, and acute eyesight.

And On to Delphinus

Those if us who own 6- to 8-inch instruments will find **NGC 6905**, in neighboring Delphinus the Dolphin, far more satisfying. An 11th magnitude oval disk measuring 44″x38″ is clearly visible even in a 3-inch telescope. The nebula's total light is somewhere around 12th magnitude, and its compact size keeps the surface brightness rather high. Its 14th magnitude central star, however, is distinct only in 12-inch or larger instruments.

The northwest corner of the dolphin's "diamond" is marked by the attractive double star **Gamma (γ) Delphini**. First discovered by F.G.W. Struve in 1830, Gamma consists of a golden magnitude 4.3 primary star and a blue-green magnitude 5.2 companion. With a separation of about 10″, resolution should be easy in nearly all telescopes. The p.a. of the secondary star is 268°. At an estimated distance of 30 parsecs, the pair is physically separated by some 300 astronomical units. Just three degrees north of Gamma is **V Delphini**, a long period variable. Small telescopes will be able to show it around its 10th magnitude maximum, but only the "big boys" will be capable of following it all the way to its minimum of — gasp! — 16th magnitude. Predictions indicate that V Delphini will reach its peak brightness in early July, and will be visible routinely over the entire summer.

Riding the western edge of Delphinus is the elusive nebula **NGC 6891**. Only by using fairly high magnification will most observers be able to detect this 10th magnitude planetary from the nearby field stars. Once confirmed, "crank up" the magnification and try spotting the 11th magnitude central star. I was able to see it in my 8-inch on a "clear" Long Island evening, so a 6-inch might be able to pull it out under dark skies. It's a more difficult task than the numbers indicate, due to the nebula's small size and high surface brightness.

Although Delphinus lies about 10° away from the Milky Way's plane, a number of galaxies can be found here. South of the dolphin's tail lie several small galaxies, the brightest of which is **NGC 6928**. Listed as a 13th magnitude SBa barred spiral, my notes recall a very faint, very small (2′x1′) glow, only seen with averted vision. Readers with access to 12-inch or larger instruments might be able to see neighboring **NGC 6927**, about 3′ to the west, and NGC 6930, an equal distance east of 6928. NGC 6927 rates only magnitude 15, and is a mere 0.5′x0.2′ in size, while **NGC 6930** is a magnitude brighter and about 1.5′x0.5′ across.

NGC 6956, a barred spiral west of 15 Delphini, is visible in an 8-inch on clear evenings. Moderate power will be required to glimpse its magnitude 13.5, 2′ diameter disk. Move 9° south for **NGC 6954**. At last year's Stellafane convention in Springfield, Vermont, I was able to see 6956 clearly, but unable to confirm 6954, which shines at 13.2 magnitude. A friend's 10-inch was capable of distinguishing its faint 1′x0.5′ shape on the same night. If you thought that 6956 was a breeze, and 6954 child's play, then **NGC 6972** will come with time. Its about the same size and brightness at 6954, and lies south of 15 Delphini. Also at 13th magnitude is the spiral galaxy **NGC 6944**. A 12-inch shows it as a 1′ disk, but only with averted vision. Even the largest amateur telescopes will have some difficulty showing **NGC 6944A**, located in the same field, which appears about the same size, but shines at a pathetic magnitude 15.5. Need I say more?

Our final two objects are both small globular clusters. **NGC 6934** displays a bright core with a few individual stars resolved around it at 240x in my 8-inch. Since it shines at 9th magnitude, even a 2-inch may detect it — but very large telescopes are needed to resolve this star group. About 34.7 kiloparsecs from Earth is **NGC 7006**, a remote globular. A 6-inch scope reveals a minute hazy patch of light, with little detail. Even at maximum magnification, a 12-inch will not resolve it. This should come as no surprise, as the brightest stars in NGC 7006 are fainter than 16th magnitude. Still, NGC 7006 presents an interesting challenge for observers, and is one of the more distant observable globular clusters.

The starry summer sky is so chock-full of exciting deep-sky views that most observers tend to stick toward the regions with bright naked eye stars, time and time again passing over less familiar regions. Yet — although faint to the eye alone — Vulpecula, Sagitta, and Delphinus all house a great variety of little-known telescopic sights; secrets of the summer sky waiting for you on any clear night this season.

Phil Harrington is an accomplished observer and writer living in suburban New York City. His last article detailed deep-sky objects in Cygnus, and appeared in Deep Sky *7.*

Small Scope Showcase

Summer Triangle, Summer Delights

by David H. Levy

I've often wondered why children are so fascinated by the Milky Way — and not just children of our generation. For millenia, this subtle band of milky light in the sky has somehow drawn our attention like a magnet. Perhaps it's the quality of light, not solid like that of a star or planet, not close and blocking like a cloud — and certainly not blinding like the Moon — but ethereal, distant, and beckoning. Perhaps also the richest part of the Milky Way is visible during summer when more people are able to observe.

But it's a bit different now; you have bought yourself a telescope and your Milky Way studies will be much more than poetic. You'll find that the Milky Way is not a band of light but in reality something both less and more thrilling. Your telescope reveals its light not as a homogeneous mass but as an apparently unrelated sea of distant stars. A loss of poetry? Perhaps. But in showing you so much more, your telescope opens up a whole new concept for you to explore, a whole new sky.

Let's begin with that part of the sky that is familiar to almost all of us, the Summer Triangle bounded by the three bright stars Vega, Deneb, and Altair. Within this area are some magnificent deep-sky objects that you can try to locate regardless of the size of your telescope or your location.

With double stars, Cygnus has one to end all. Simply sight along the neck of the swan, all the way to the head which is β **Cygni**, or Albireo. One star to the unaided eye, it splits easily in your telescope's eyepiece to reveal two. Note the striking contrast of colors as well as the rich background of Milky Way stars. (A friend of mine was once showing this pair to a beginner, explaining that the two stars revolve around each other. "Yes," the neophyte interrupted before she could mention that their period of revolution was more than 600 years, "I can see them doing that now!")

A second pair is right next to Vega: ε **Lyrae** is the "Double-Double" star. The components of each pair are separated by so little that you may need a good quality 6-inch telescope to split them. A considerable margin separates the two pairs, however — can you do it by naked eye? Splitting them without any optical aid is a test both of the acuity of your eye and the clarity of your night. Near the middle of Montreal on one clear steady night I succeeded, so the night doesn't have to be very dark, just steady.

Not far from the Double-Double is a deep-sky object of a different type. It's not a star; actually it is the remains of an atmosphere of a star — gas gently puffed out long ago. This is the **Ring Nebula**, number 57 in Charles Messier's Catalogue. One of the easiest deep-sky objects to find (regardless of telescope size or location), M57 is a fine example of a planetary nebula. In a small telescope (a 3-inch, say) from city skies, it looks like a star out of focus. With a larger telescope the object takes on shape, first as an oval and then with more aperture and magnification as a "smoke" ring. If you want to see the nebula's central star, you need the best possible skies and an aperture of at least 12 inches. Even then, the best you'll likely see is an occasional averted-vision glimpse of a barely visible star. There is some evidence that the ring's central star may be slightly variable.

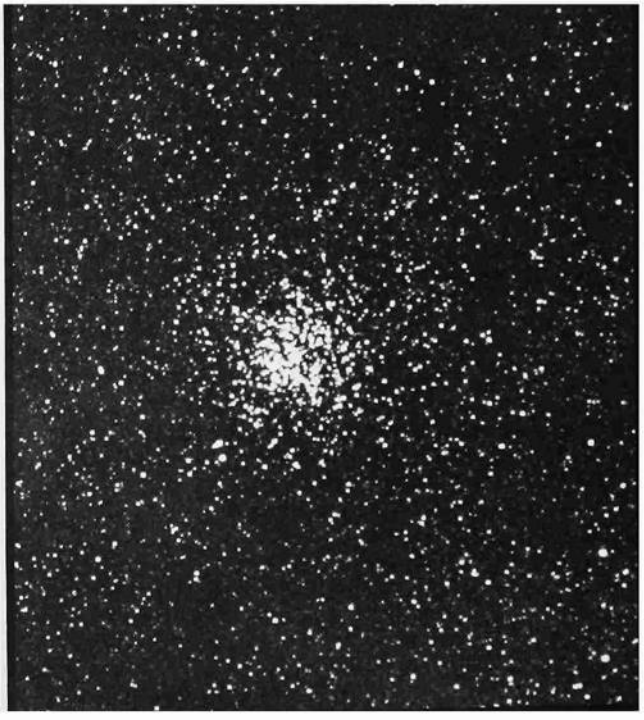
But this is not the only bright planetary in the environs of the summer triangle. Not far from β Cygni is the **Dumbbell Nebula**, M27. This does not look like a smoke ring, rather a bowtie-shaped smudge of fuzzy light. M27, by the way, is named after its approximate shape, not its discoverer!

Let's move further south along the Milky Way into Scutum, where we'll meet one of the most delightful objects in the entire heavens — **M11**,

The Ring Nebula (M57) in Lyra

Paul Roques

The Wild Duck Cluster (M11) in Scutum



Thomas L. Dessert

sometimes called the Wild Duck Cluster for its resemblance to a flock of birds in flight. M11 is a tight open cluster, a grouping of stars where we see easily the individual members. In the case of M11, however, the stars crowd together more than in other open clusters such as the Pleiades.

M11 looks good with almost any telescope at almost any power, and in fact you can have a lot of fun trying different magnifications with this cluster. With small scopes and low power you see a bright bluish smudge and, as you increase the power, the cluster resolves easily into its component stars. Telescopes of 5-, 6-, and 8-inches' aperture make the stars look more distinct and also provide a greater contrast between the bright starfield and its darker background. As you explore M11 this way you can't help making the same discovery others have — that there's really not one M11, but many. Different telescopes and eyepieces offer new impressions of the same object, so your viewing fun is multiplied. Although this is true for every celestial object, it's especially so for M11.

Now let's move even further south, to the **Hub of our Galaxy**: the Milky Way's brightest section in Sagittarius. The first thing you should look at here is — nothing in particular! Put your lowest power eyepiece into the focuser and just sweep the telescope from field to field, seeing how many double stars, clusters, nebulae, and other interesting things drift past your gaze.

If we lived in the southern hemisphere, the Milky Way in Sagittarius would dwarf the Cygnus section both in brightness and size. Thus our telescopes are vital for appreciating fully the wonders and surprises we see in this rich menagerie of deep-sky objects. Let's begin with the **Omega Nebula**, M17. Of all the Messier objects, this is my favorite — so-judged after a single all-night frenzy of observing all of Messier's catalogued objects.

It's not the largest or brightest Messier object, but through my 16-inch I found this exquisite nebula to exceed even the Orion Nebula in both complexity of structure and delicacy of wispy nebulosity. But whatever size of telescope you have, with this object it is important to use an eyepiece that provides both magnification and a wide field — you want to see detail in the nebula as well as the contrast between the object and the sky background. If you have a nebular filter, use it — it will be very helpful under an urban sky, while from a dark country site, the view is excellent both with and without one.

If you ever get through with M17 (unlikely!) — try nearby **M22**, one of the nicest globular clusters you'll ever see and, because of its far southern declination, not as well known to U.S. and Canadian observers as it should be. The cluster is rich in two ways, first because of the dense concentration of its stars and, second, because of the rich field of unrelated Milky Way stars in which the cluster resides. Quite a treat!

Onward and deeper into the south, for two fine emission nebulae. M8, the **Lagoon Nebula**, is a bright diffuse mass of hydrogen gas, a stellar nursery. Objects like M8 look really good in UHC and nebular filters, but remember that the observational price of every filter — even those that enhance one feature extremely well — is that less light comes out the back end. Close by M8 is M20, the **Trifid Nebula**, an emission nebula whose dark lanes divide it into three distinct parts, which you can see under a good sky with some magnification.

Let's finish with one more globular cluster, but this one lies off the Milky Way a bit. Hercules, with its magnificent spectacle of **M13**, is well placed high in the sky throughout the summer months. Easily found even with a 3-inch telescope, M13 is "cordon bleu" for even the most sophisticated visual palate.

Most of the objects we looked at this month have "M" or Messier numbers. Neophytes sometimes wonder just who this Charles Messier was, anyway? An eighteenth century French comet hunter who used 2- and 7-inch refractors, Messier was one of the earliest of the competitive comet finders. In his annoyance at finding dozens of little cometlike objects that later turned out to be non-moving galaxies, clusters, and nebulae, he made a catalog of these "comets that aren't." The real comets he discovered (about 15, according to Harvard astro-historian Owen Gingerich) have all gone, but his famous catalog still provides an accurate guide to the delights awaiting you in the realm of the ethereal and mysterious deep sky.

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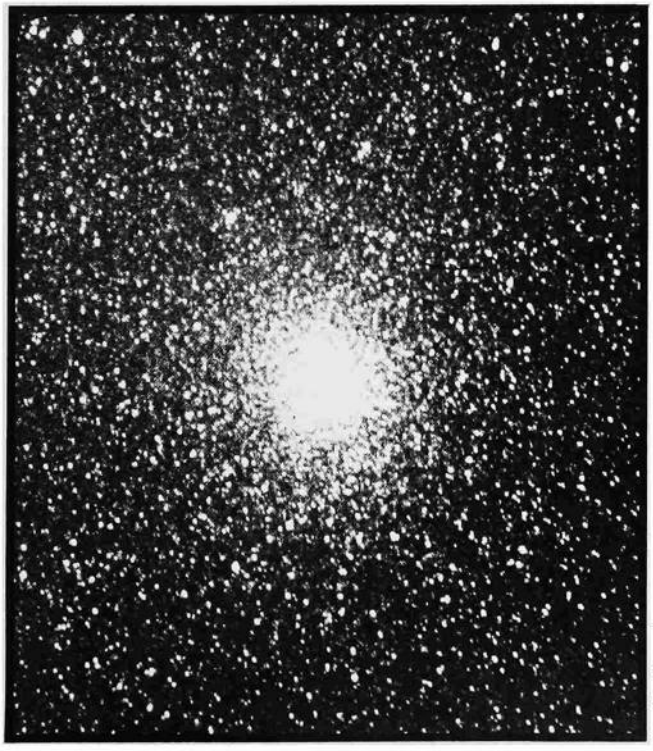
Globular Cluster M22 in Sagittarius



Lee C. Coombs

The Trifid Nebula (M20) in Sagittarius

Martin C. Germano

Stars in Need:
Symbiotic Variables

by Dave Kratz

Observing deep-sky objects from moderately or heavily light-polluted areas is a challenge facing many *Deep Sky* readers. With this in mind, I compiled a list of deep-sky objects which could be observed from even heavily light-polluted areas. Owing to their small angular size, high surface brightness, wide range of shapes, and narrow-band emission of light, planetary nebulae seemed the best choice (see *Deep Sky* 6, Spring 1984). While organizing the planetary nebula list, however, I discovered that a number of objects were misclassified as planetaries. Prominent among the misidentified objects is a curious group of objects known as symbiotic variable stars. Indeed, of the 112 symbiotic stars listed by astronomer David A. Allen in 1979, 46 were listed in L. Perek and L. Kohoutek's 1967 work *Catalogue of Galactic Planetary Nebulae*.

What is a symbiotic variable star? What is its place in the grand scheme of the universe? Just over 50 years ago, Paul Merrill and Milton Humason — working at Mount Wilson Observatory — called attention to the existence of a rather peculiar group of stars, which included only AX Persei, RW Hydrae, CI Cygni, and possibly T Coronae Borealis and R Aquarii. Borrowing upon his botanical background, Merrill called these stars *symbiotic* because they appeared as one star but showed spectra with absorption features indicating a cool M-type giant star (about 3500 K) *and* emission lines indicating a temperature of about 50,000 K. Such red giants are prominent in the spectra of planetary nebulae — hence the misclassification. At the conclusion of the Mount Wilson Hα emission survey, nearly a dozen symbiotic variables had been identified. The star Z Andromedae became the prototype for the group, as it was the first symbiotic star to have its spectrum thoroughly studied.

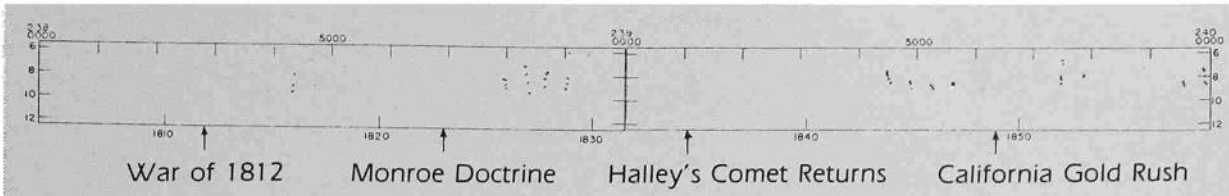
The mysterious nature of symbiotic stars misled astronomers for some time before they unraveled the problem. Since their light output was erratic, the earliest-known symbiotic stars bore variable star designations. Merrill's pioneering work in the field provided valuable knowledge about their behavior: when such a star is near minimum, the spectrum of an M-type giant dominates — when a symbiotic star rises near maximum, a hotter shell spectrum takes over. But a composite spectrum alone does not make a symbiotic star — dwarf novae like U Gem and SS Cyg show such a spectrum, but they are indeed different types of stars.

In 1969 Alexander Boyarchuk produced a better definition for a symbiotic variable, largely based on his detailed investigations. A symbiotic variable must meet the following criteria: (1) its spectrum must show absorption lines indicating a late spectral type; for instance, bands caused by titanium oxide or zirconium oxide and lines caused by calcium I and calcium II; (2) its spectrum must also show emission lines caused by ionized atoms such as hydrogen I, helium II, oxygen III, neon III, and sulfur II; (3) these emission lines must be narrow, not exceeding a value of 100 kilometers per second; (4) the suspected symbiotic star must be variable in light output.

Unfortunately, only about 20 stars fulfill Boyarchuk's rigid criteria. It was David A. Allen, who upon finding Boyarchuk's criteria too restrictive, broadened them to include 112 stars. Recently Boyarchuk put forth a "working definition" a little less specific than his original, due to the fact that a common agreement on what a symbiotic star is has yet to be reached. The working definition says that such a star "must have a spectrum simultaneously showing cool stellar lines of helium II and/or oxygen III and/or neon III, and possibly even lines requiring higher ionization energies; and that the object varies on fairly large time scales."

While recent observations in the radio, infrared, visible, and X-ray parts of the spectrum have wreaked havoc on the definition of a symbiotic variable, they have also increased our knowledge about the nature of these strange objects.

From visible light alone, astronomers concluded that symbiotic variables are binary star systems consisting of two stars and an enveloping blanket of nebulosity. They have a cool red giant star, which provides the main absorption features similar to those found in Mira-type stars and semi-regular variables, a hot, compact star which produces the exciting radiation found in various emission lines, and a small nebula consisting of ionized gas and glowing fainter than a typical planetary nebula. The typical mass for a nebula in a symbiotic system is 0.0001 solar mass, compared with 0.2 solar mass for a typical planetary nebula. A few astronomers disagree with this interpretation and believe that a single star



This light curve for the symbiotic star R Aquarii spans 167 years, and shows how as observations become abundant, the nature of variation becomes clear. Courtesy AAVSO. Continues overleaf

is responsible for a symbiotic variable. They encounter problems in explaining the mechanics of a single-star system, however, so that the binary star model is the overwhelming favorite. A few objects — most notably V1016 Cygni — seem to fit the single star explanation. But many astronomers theorize that V1016 Cygni is a planetary nebula in the early stages of formation, rather than a symbiotic star.

Supporting evidence that symbiotic stars are binaries comes from a number of observations. The locations of spectral features displayed by symbiotic stars — indicating different physical conditions coexisting in the same star system — is best explained by having two stars there. The measured radial velocity curves for various spectral lines are consistent with a binary system. Several symbiotic stars are confirmed eclipsing binaries, obviously composed of two stars.

Ultraviolet and infrared observations also indicate that symbiotic stars are binaries. From infrared data, two types of symbiotic variables have been proposed: S-type, 75% of total, only low-temperature star colors observed in the 1 to 4 micron region; and D-type, 25% of total, circumstellar dust at a temperature near 1000 K observed. There is perhaps a third class, D′, containing a few examples of hotter stars (G-type) with much cooler dust. In addition, the infrared variability of these objects separates them from normal late-type giant stars, which vary in large amplitude in visible light. The infrared data also distinguishes those variables with poor nebular spectra or rich nebular spectra. The ultraviolet data, mostly from the *International Ultraviolet Explorer* satellite, shows the continuum of the hot component; in combination with the infrared and visible light data, it is used to create a picture of the entire star system.

Other regions of the spectrum have contributed knowledge toward deciphering the symbiotic stars. In the radio part, where only about 10% of the symbiotic variables have yet to be detected, clues are found regarding a star's expanding shell or hot stellar wind. The X-ray observations from the HEAO 2 *Einstein* satellite — which has discovered the symbiotic stars AG Draconis, HM Sagittae, V1016 Cygni, and RR Telescopii — yield information on the mechanisms powering these systems. Nearly every part of the electromagnetic spectrum plays an active role in supplying clues to these mysterious stars!

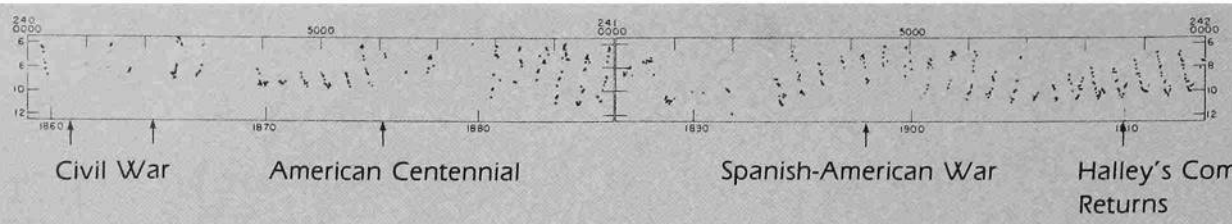
Despite all that we've gathered about these stars, it is hard to place them into the grand scheme of stellar evolution. Because the hot stars in a symbiotic variable lie near planetary nebula central stars on a color-magnitude diagram, some astronomers have proposed that symbiotics develop into planetary nebulae! This is also based on two stars — HM Sagittae and V1016 Cygni — which appear to be intermediate objects between planetaries and symbiotic systems. The problem in following this lead is that the central stars of planetaries are exceedingly faint and difficult to study, but the rate at which they're being looked at is increasing so the next couple of decades will surely answer many questions about them.

At the current level of understanding, symbiotic variables are members of a family also containing cataclysmic binaries and double-core planetary nebulae. The differences among these objects are due to stellar masses, orbital periods, and mass-transfer between the stars. A reasonable scenario for the formation of a symbiotic variable is as follows: it starts with a binary system having an orbital period of one or two years and an orbital separation wide enough to let the primary's helium core ignite before it extends out to the Roche lobe. (The Roche lobe defines the outer limit of a star's gravitational force upon small bodies.) The initial mass of the primary is probably two to four solar masses: when the star's helium begins burning, it forms a degenerate carbon/oxygen core. This core is surrounded by an extensive envelope which expands at the rate of nuclear burning inside the core.

As the primary reaches its Roche lobe, a rapid transfer of material onto the secondary star begins. The envelope of material becomes deeply convective, and the process of mass-transfer to the secondary speeds up. The system is now ready to enter the symbiotic phase of its evolution; the more massive secondary, having "gained weight" from the primary, develops into a red giant. The primary, now a white dwarf, initiates thermonuclear reactions within the hydrogen and helium envelope.

With the exception of eclipsing binaries, nearly all symbiotic stars exhibit irregular and unpredictable fluctuations in brightness. Sometimes they show flare-like activity, while at other times their magnitude remains fixed for months or years. They are unusual enough that astronomers deal with symbiotic stars as individuals and hesitate to lump them together into generalizations. Most symbiotic stars have light curves, at least in part, resembling that of Z Andromedae — the prototype — and are characterized by four types of behavior. First, their brightness often changes very little — sometimes for periods of up to several years. From 1932 to 1938, Z Andromedae remained nearly constant in light output. And again from 1950 to 1959. And again from 1973 to 1977. At other times, however, symbiotic stars show semi-periodic fluctuations in brightness with amplitudes of up to one full magnitude. In the early 1940s and late 1960s, Z Andromedae behaved in this manner. At still other times, the fluctuation in brightness is chaotic and irregular. And sometimes major flares occur, with amplitudes as high as four magnitudes — like those demonstrated by Z Andromedae in 1914, 1939, 1959, and 1969.

Considering all these crazy patterns of behavior, how do you go about observing a symbiotic variable star? Basically, use the same techniques as you would for monitoring a long-period variable star. These are outlined in great detail in Margaret Mayall's book *Manual for Observing Variable Stars* (available from the AAVSO, 187 Concord Ave., Cambridge, MA 02138); I'll briefly discuss them here. You should be very careful when identifying a variable or comparison star, and make sure to use only so-called standard comparison stars since they are well-studied and known to be unwavering in brightness. Whenever possible, the variable and comparison stars should lie in the same field of view, differ in brightness by less than half a magnitude, and be of similar color. Use just enough magnification to see the variable and comparison stars — don't go overboard with high powers. For instance, with CH Cygni — which varies between magnitudes 5.8 and 8.4 — good for binoculars (or a telescope when the star is near minimum). A good number of symbiotic variables, thankfully, are fairly bright and can be viewed with



6-inch or 8-inch telescopes. Unfortunately, some of the symbiotics show a reddish tinge. While not as severe as some of the long-period variables, the reddish color poses problems in estimating magnitudes due to the Perkinje effect — that red stars tend to excite the retina more than blue ones, and should not be stared at for long periods. Quick glances at ruddy stars usually eliminate this problem.

Let's now look at some representative examples of symbiotic stars.

Z Andromedae, the prototype of the symbiotic variable group, is located approximately 1° east-northeast of the small open star cluster NGC 7686. As noted, fluctuations characteristically range in amplitude from several tenths of a magnitude to approximately three magnitudes. These bright outbursts are attributed to activity of the hot blue subdwarf, while smaller variations in brightness are caused by the intrinsic variability of the M2III red giant. The brightest recorded magnitude for Z Andromedae was 7.9 in the summer of 1939. When inactive, however, the variable normally remains at magnitude 11.

R Aquarii is a more fascinating and complex variable. Its inclusion into the list of symbiotic variables has been debated, although its morphology tends to confirm that R Aquarii is a valid member of this group. The object consists of an M7e Mira-type long-period red giant, a B2 subdwarf whose absolute magnitude is only half again as bright as the Sun's, and rather extensive surrounding nebulosity. Over the last century, R Aquarii has exhibited a light curve characteristic of fairly regular long-period Mira-type variables, averaging magnitude 4.5 with a period of about a year. Between 1928 and 1934, however, the continuous spectrum of the blue subdwarf became so strong that the maximum brightness of the R Aquarii fell by almost two magnitudes and the range of its light variations decreased to around magnitude 1.5. Normally ranging between magnitude 6 and 11, R Aquarii's faintest recorded magnitude was 12.4 in 1974. Since then, it has remained comparably faint. Could this object be entering another peculiar phase? Possibly, for it has also been determined that R Aquarii is an eclipsing variable with a period of 44 years and an eclipse duration of about 8 years. The last eclipse occurred between 1974 and 1982 and the next is expected between 2018 and 2026. R Aquarii is also surrounded by a peculiar lens-shaped nebulosity, which extends approximately 2′ out and is composed of curved filaments located symmetrically around the variable. R Aquarii is embedded in a small nebulous disk which itself appears variable in brightness. According to W. Baade, the outer nebula has an expansion velocity of 80 to 100 kilometers per second, indicating that a nova-like outburst of the blue subdwarf must have occurred approximately 600 years ago, which would place R Aquarii at a distance of about 260 parsecs.

Located about 1° south-southeast of Epsilon Coronae Borealis is T Coronae Borealis — the "Blaze Star" — the best known example of a recurrent nova. Here again, it is debatable as to whether this is a symbiotic variable. Nevertheless, this system consists of a 2.1 solar mass blue subdwarf virtually in contact with the outer atmosphere of a 2.9 solar mass M3 red giant; a circumstellar shell of material surrounds the entire system. Although the intervals between and the amplitudes of T Coronae's eruptions are considerably greater than those for other symbiotic variables, its physical characteristics tend to confirm its symbiotic nature. Two outbursts have been observed for this object: In May 1866, the variable's magnitude rose from 10.8 to 1.8 in just over two days, then declined to magnitude 8 in less than 20 days (a true nova usually takes about one year to decline from maximum brightness); in February 1946, a similar rise to third magnitude and subsequent fall was recorded. These outbursts have been of such short duration that it is quite possible others have occurred.

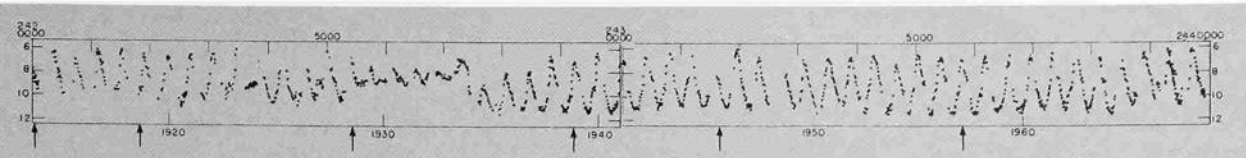
BF Cygni is a more typical example of a symbiotic variable. Located only 4.5′ northwest of a magnitude 5.7 star and 100′ east-southeast of M56, BF Cygni consists of an M5III red giant and a blue subdwarf and varies between magnitude 9.3 and 13.5. It is located in a region rich with variable stars, but unfortunately, only temporary finder charts are available for this object.

CH Cygni — AAVSO's "Star of the Year" in 1982 — is composed of an M6III red giant and a hot blue dwarf embedded in an excited nebulosity. Located about 100′ southwest of Iota Cygni, CH Cygni varies between magnitude 5.8 and 8.4. it possesses both short-period (around 100 days) and long-period (greater than 700 days) light variations superimposed upon its light curve. This variable had been unusually bright from 1977 up until July 1984, when it finally dropped from magnitude 5.8 to 6.4. In November 1984, its magnitude fell to 7.0. Viewed by this author on two occasions, in January 1985 CH Cygni appeared as a magnitude 7.2 object with a distinctive slightly orange color, as opposed to an August 1983 observation which gave an estimated magnitude of 6.1 and no distinctive color. Located 20′ east-southeast of CH Cygni is the magnitude 14.3 double galaxy IC 4867.

CI Cygni, located approximately 1.5° northwest of Eta Cygni, is a symbiotic variable normally possessing a half-magnitude amplitude in light variation. However, three major flares have been observed: In 1911, CI Cygni brightened by about two magnitudes, and in 1937 and 1971 it increased by three. This object is also considered an eclipsing binary, with a period of two-and-a-half years.

Located nearly midway between Nu Ophiuchi and M14 is RS Ophiuchi, a symbiotic variable with traits similar to those of T Coronae Borealis. Eruptions were observed there in 1898, 1933, 1958, and 1967. On each occasion — as with T Coronae Borealis — the rise to maximum brightness occurred within one to two days and then fell off fairly rapidly. Usually RS Ophiuchi has an apparent magnitude of about 11; however, the 1933 outburst sent the star to magnitude 4.3, and to magnitude 5.0 in 1958. During the latter eruption, the variable color appeared white at maximum brightness, but turned deep red within a few days as hydrogen-alpha emission dominated the spectrum.

The light variations of AG Pegasi are altogether different from those of other symbiotic variables. Before 1850, the object held essentially constant at magnitude 9.1. From 1850 to 1870, it slowly brightened to magnitude 6.2. Since then, a gradual decline has brought AG Pegasi to its present brightness of about magnitude 8. Recent observations have shown the visual magnitude to vary between 7.7 and 8.8, with



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Model for a Symbiotic Variable

1. Cool component
- **Spectral type: M or K giant**
- **Diameter: $\sim$100 $D_\odot$**
- **Surface Temperature: $\sim$3500 K**
- **Absolute Visual Magnitude: -0.5**

2. Hot component
- **Spectral type: Be dwarf or subdwarf**
- **Diameter: $\sim$0.5 $D_\odot$**
- **Surface Temperature: $\sim$50,000 K**
- **Absolute Visual Magnitude: $+0.5$**

3. Nebula
- **Mass: $\sim$0.0001 $M_\odot$**
- **Diameter: $\sim$50,000 $D_\odot$**
- **Temperature: $\sim$17,000 K**
- **Electron Density: 5×10^6 cm^{-3}**

Art by Thomas L. Hunt

Manned Moon Landing

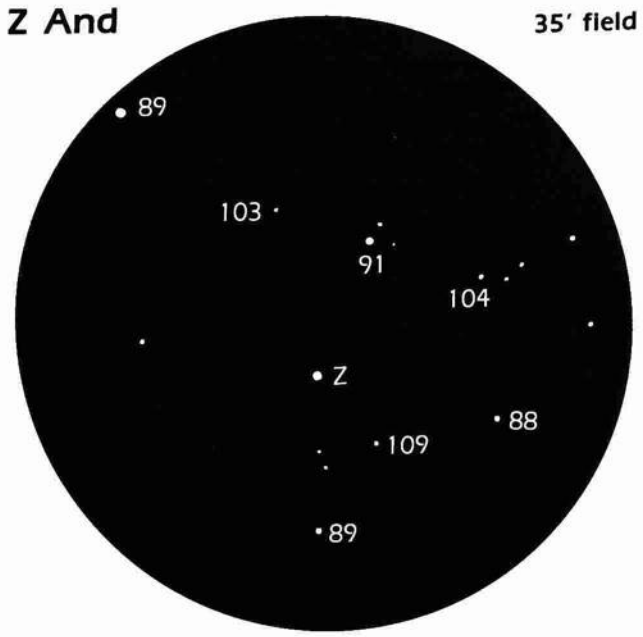
American Bicentennial

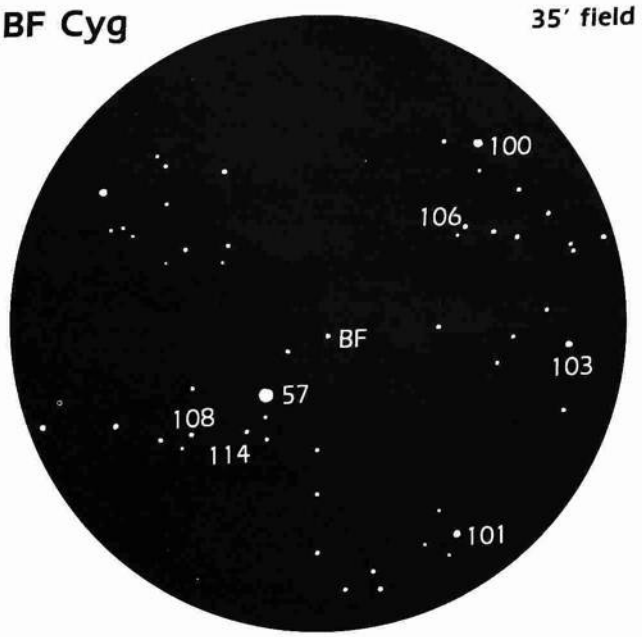
Halley's Comet Returns

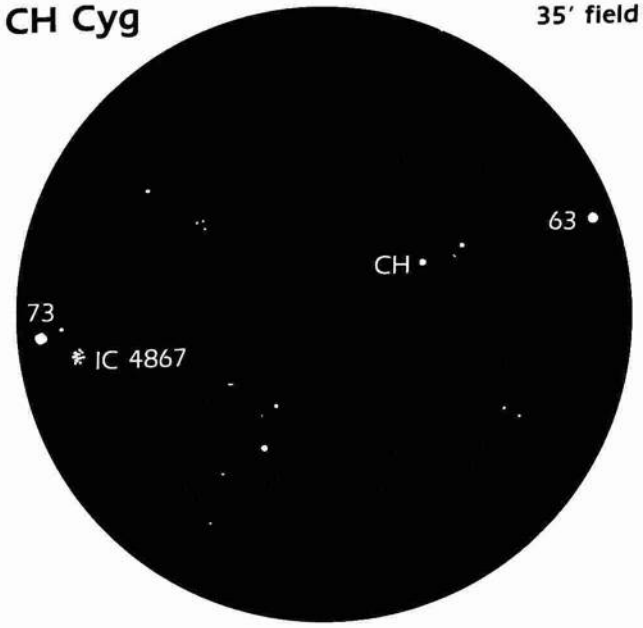
Selected Symbiotic Variables

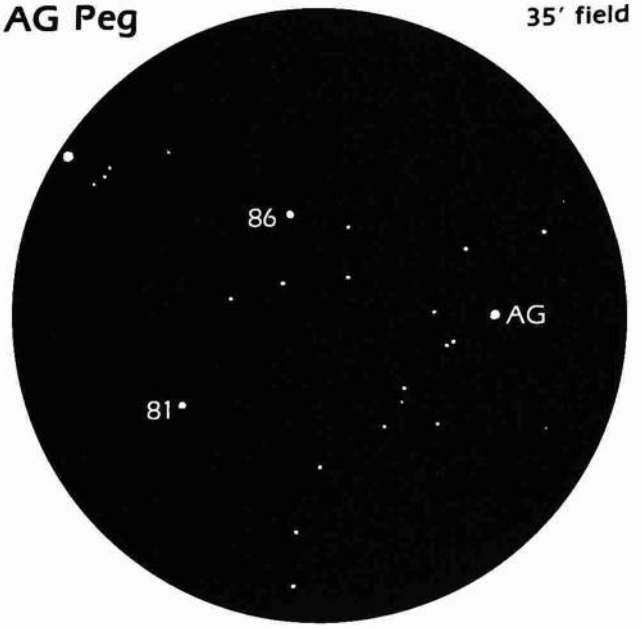
Star	R.A.(2000)Dec.	Mag.	Chart	Notes	IR
Ax Per	01h36.3m +54°16′	9.7–13.4	T		S
Minkowski 1-2	01h58.8m +52°54′	14.0		misclassified planetary	D
UV Aur	05h21.8m +32°31′	8.2–10.0			
RX Pup	08h14.2m −41°42′	11.1–14.1			D
SY Mus	11h32.2m −65°25′	11.3–12.3			S
RW Hya	13h34.3m −25°23′	10.0–11.2			S
T CrB	15h59.5m +25°55′	2.0–10.8	A		S
AG Dra	16h01.7m +66°48′	9.1–11.2	T		S
HK Sco	16h54.7m −30°23′	13.1–15.8			S
CL Sco	16h54.9m −30°37′	11.2–13.9	N		S
V455 Sco	17h07.4m −34°05′	12.8–16.5			S
Th 3-17	17h27.5m −29°03′	14.0		misclassified planetary	S
Th 3-18	17h28.4m −28°39′	12.6		misclassified planetary	S
Th 3-30	17h33.7m −28°07′	13.1		misclassified planetary	
Th 3-31	17h34.3m −29°29′	13.6		misclassified planetary	S
RT Ser	17h39.9m −11°57′	14.6			S
UU Ser	17h42.6m −15°25′	11.4			
RS Oph	17h50.2m −06°42′	5.3–12.3	A		S
V2416 Sgr	17h57.3m −21°41′	—			S
V615 Sgr	18h07.7m −36°06′	—			
V2506 Sgr	18h11.0m −28°33′	—			S
Y CrA	18h14.4m −42°51′	12.0–12.9	N		S
V2756 Sgr	18h14.6m −29°49′	—			S
YY Her	18h14.6m +20°59′	11.7–13.2	T		S
AR Pav	18h20.5m −66°05′	10.2–12.7		eclipsing variable	S
V443	18h22.1m +23°27′	12.4–12.9			S
FN Sgr	18h53.9m −18°60′	9.0–13.9	N		S
V919 Sgr	19h03.8m −16°60′	10.5			S
CM Aql	19h03.6m −03°03′	16.5			
BF Cyg	19h23.9m +29°41′	9.3–13.5	T		S
CH Cyg	19h24.5m +50°14′	5.8–8.4	A		
HM Sge	19h41.9m +16°45′	11–17	T	embryonic planetary?	D
CI Cyg	19h50.2m +35°41′	9.4–13.7	T	eclipsing variable	S
V1016 Cyg	19h57.1m +39°50′	10.0–15.5		embryonic planetary?	D
RR Tel	20h04.3m −55°44′	6.5–16.5	A, N		D
V1329 Cyg	20h51.0m +35°35′	11.5–19.0	T		S
V407 Cyg	21h02.2m +45°46′	16.0			
AG Peg	21h51.0m +12°38′	6.8–8.2	T		S
Z And	23h33.7m +48°49′	8.0–12.4	A		S
R Aqr	23h43.8m −14°44′	5.9–11.4	A	eclipsing variable	

A – Standard AAVSO
T – Temp AAVSO
N – RAASNZ









Sketches by Dave Kratz (field star magnitudes given with decimals omitted)

semiregular behavior at maxima every 600 to 700 days. in 1967, Alexander Boyarchuk derived the spectral types of M3III and WN6 and reported that the Wolf-Rayet star resembled the nucleus of a planetary nebula. The star FG Sagittae (ASTRONOMY, October 1983, p. 74) has shown activity during the past 80 years reminiscent of the activity of AG Pegasi from 1850 to 1870, and is surrounded by the planetary nebula Hel-5. Located about 3.3° north-northeast of Enif, AG Pegasi is definitely a star to watch.

Lying 3° north-northwest of M76 is AX Persei, a variable with a highly-irregular light curve similar to that of Z Andromedae. Correspondingly, a flare on AX Persei in 1955 appeared almost identical to those viewed on Z Andromedae.

Our final object, HM Sagittae, is situated approximately 1° south-southeast of midway between Alpha and Beta Sagittae. While is it considered by some to be the nucleus of a protoplanetary nebula, the spectrum of this object is similar to those of other symbiotic variables. In 1975, HM Sagittae increased more than five magnitudes, brightening to magnitude 11 where it has since remained.

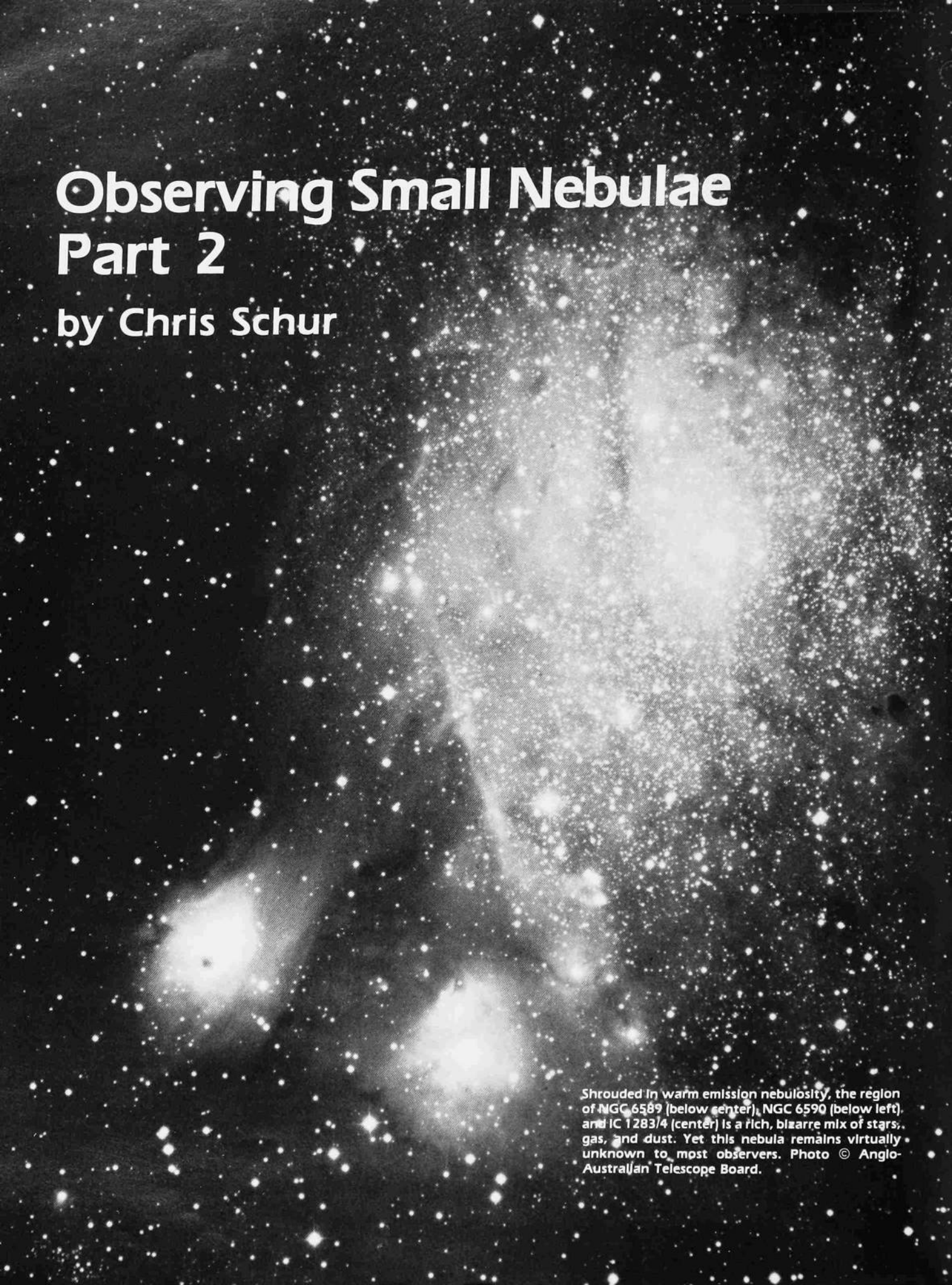
In observing symbiotics, remember that as with planetary nebulae, these objects contain emission line spectra. Therefore, spectroscopic techniques used to identify planetary nebulae can also be used with symbiotic variables. However, the main emission features for the two types of objects differ. For planetary nebulae, the two doubly ionized oxygen forbidden transitions at 507A and 4959A are most prominent, giving these objects a greenish color. For symbiotic variables, Hα at 6563A in the red dominates, with Hβ at 4861 in the blue also contributing.

Because symbiotic variables are such strange objects with widely-ranging characteristics, they are a phenomenon holding great opportunity for the backyard observer.

Dave Kratz is a graduate student at the State University of New York at Stony Brook, and a long-time active deep-sky observer. His last article, "Observing Planetary Nebulae," was featured in DSM *#6.*

Observing Small Nebulae Part 2

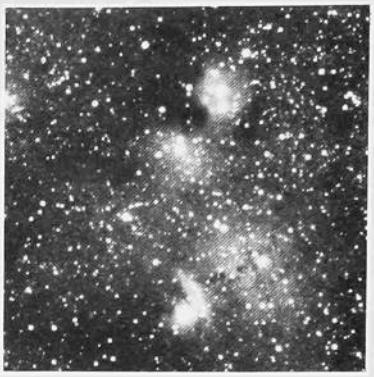
by Chris Schur



Shrouded in warm emission nebulosity, the region of NGC 6589 (below center), NGC 6590 (below left), and IC 1283/4 (center) is a rich, bizarre mix of stars, gas, and dust. Yet this nebula remains virtually unknown to most observers. Photo © Anglo-Australian Telescope Board.

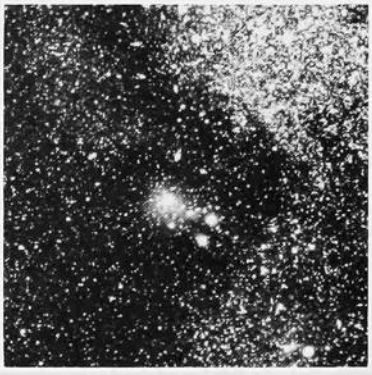
Complex nebulae consisting of both dust and ionized gas, IC 59 and IC 63 surround the bright variable star Gamma (γ) Cassiopeiae. Lick Observatory photo.

NGC 6559 — together with IC 4685, IC 4678, IC 1274, and IC 1275 — is a large emission nebula complex due east of the Lagoon Nebula. Photo by David Healy.



Part of the vast Rho (ρ) Ophiuchi dust complex, IC 4601 appears as a double knot of reflection nebulosity. Photo by E.E. Barnard.

South of M24 is the NGC 6589 region, which also includes NGC 6590 and IC 1283/4 (see opposite page). Photo by E.E. Barnard.



South of IC 4601 and still within the Rho Oph complex is the reflection nebula IC 4604 — a very faint target. Photo by E.E. Barnard.

Sharpless 2-82 is a small emission and reflection region in Sagitta — try spotting it using a 10-inch or larger telescope. Photo by E.E. Barnard.

Are you tired of looking at the Lagoon Nebula for the 596th time? Do you need something different to swing your scope toward this summer? Fortunately, the summer Milky Way holds an impressive collection of small nebulae — most of which are completely unknown to all but a handful of observers. The majority are plotted on Tirion's *Sky Atlas 2000.0*, but only as tiny green boxes amidst larger, brighter deep-sky objects. Many of these nebulae are — by comparison to average galaxies — quite faint. But a medium (8-inch) to large (16-inch) telescope under dark, moonless skies will show many of these nebulae as ghostly patches of soft light.

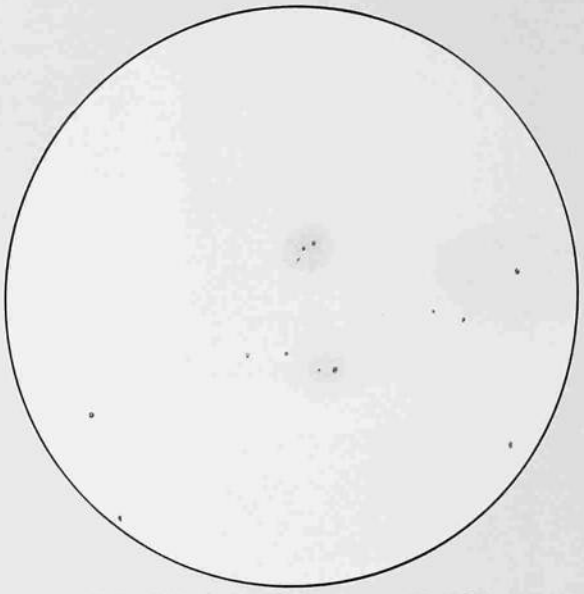
Several impressive nebulae lie in the constellation Scorpius, one of which lies just 3° west of the Stinger. **NGC 6334** is a fine reflection nebula containing an eighth- magnitude central star. This nebula appears brighter on its northern edge with several faint stars embedded in the nebulosity. About 15′ north of this bright patch is a smaller detached cloud of nebulosity which is also a member of the NGC 6334 complex.

Sweeping eastward into Sagittarius, the selection becomes richer. Here we find many complex regions of intermixed dust and gas among numerous tiny stars. One of the finest lies among just a field's diameter east of the great Lagoon Nebula — the **NGC 6559** group. NGC 6559 appears as an unusually bright oval glow surrounding two 10th magnitude bluish stars, the whole cloud measuring perhaps 5′ across. While observing this nebula with my 16-inch telescope, I installed a Deep-Sky Filter from Lumicon and was surprised to see a long, shimmering "river" of nebulosity west of NGC 6559. This was **IC 4685**, the brightest portion of an extensive area of faint reflection nebulosity in this region.

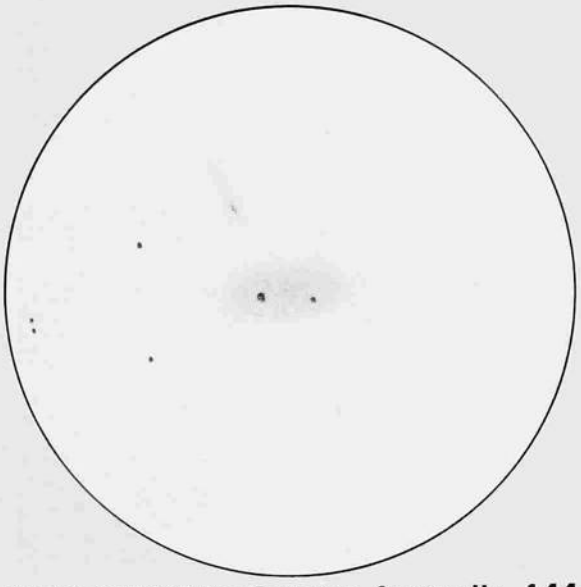
Moving northward to the southern edge of the great starcloud M24, we come upon **NGC 6589** and **NGC 6590**. These twin circular clouds present a great spectacle to users of rich-field telescopes or other observers with wide fields of view. Each cloud is centered on a small group of 10th and 11th magnitude stars and both are separated by about 10′ The objects lie in the center of a large dark cloud representing the unilluminated portion of the same complex. Nearly every star in this otherwise rich portion of the Milky Way is blotted out by obscuring dust.

All sketches made by Chris Schur with a 16-inch f/5 Newtonian, save NGC 7129/33, made with an 8-inch telescope.

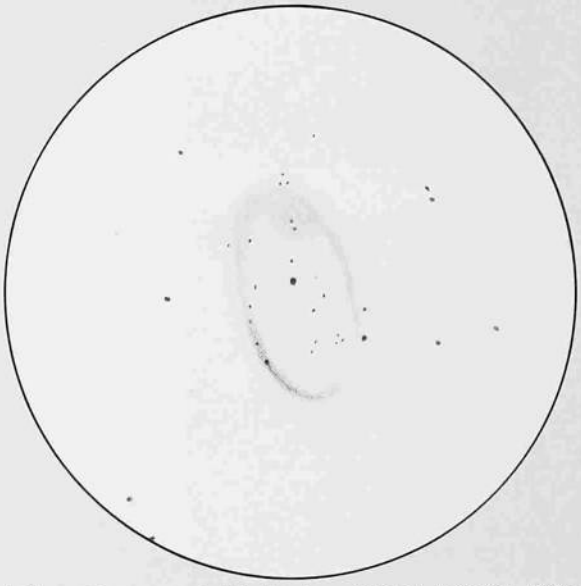
NGC 6559 (center) and IC 4685, 90x



NGC 6589, NGC 6590, and IC 1283/4, 90x



NGC 6726/7 in Corona Australis, 144x



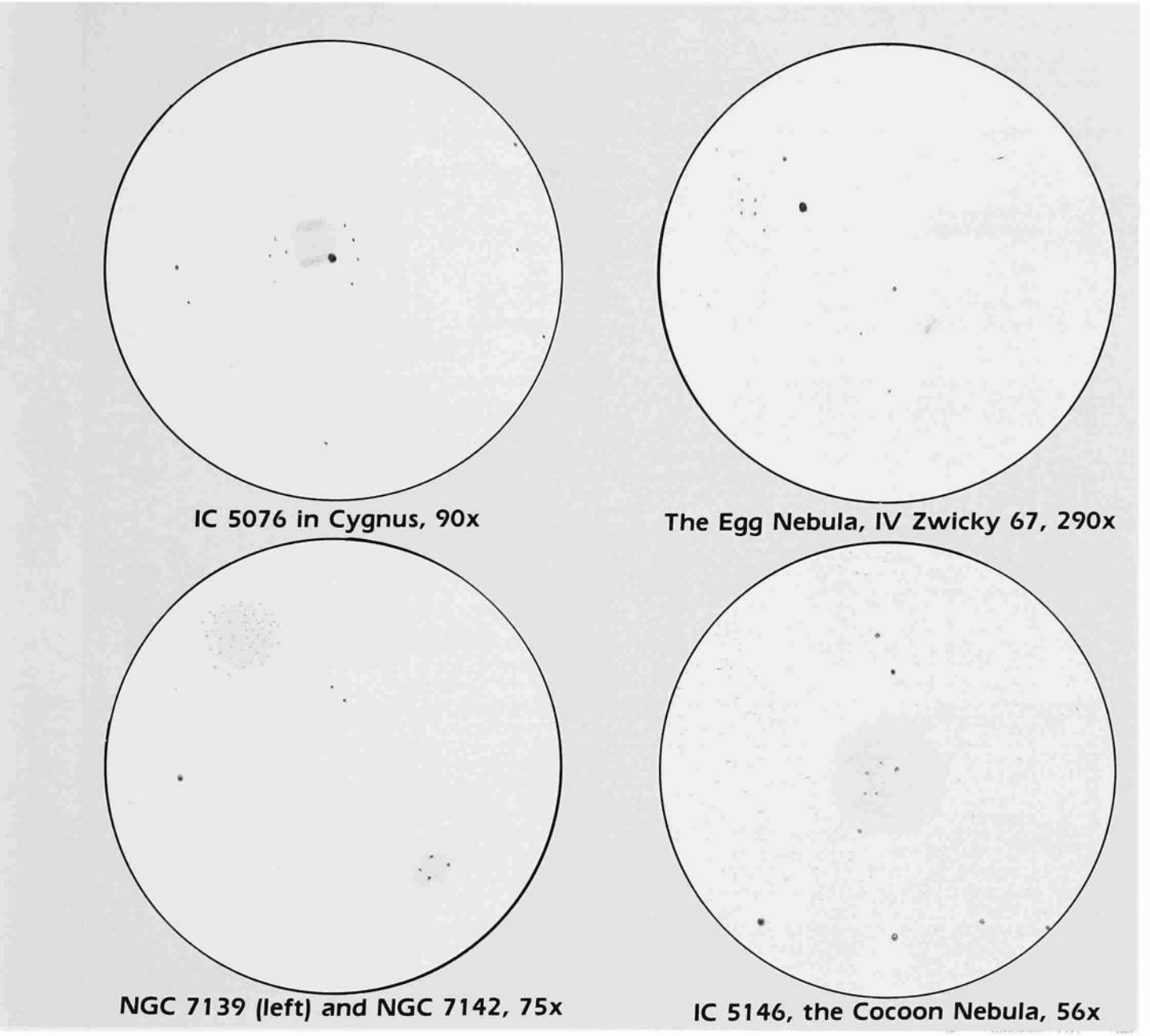
The Crescent Nebula, NGC 6888, 90x

Just northeast of this pair is the very faint and much larger, two-part nebula designated **IC 1283** and **IC 1284**, barely visible as an elongated oval surrounding a ninth-magnitude star.

Next, sweep your scope 3° directly south of the Lagoon Nebula. You should come upon the dazzling open cluster NGC 6520 and the rich black dust nebula **Barnard 86**. This "hole in space" is one of the best and most easily found examples of a small dark nebula; it is so opaque that it is visible in most any telescope at the proper magnification.

For a rapid change of pace, sweep southward below the Teapot to the small arcing constellation Corona Australis. Although it is low on most northern hemisphere horizons, the small chained nebula made up of **NGC 6726** and **NGC 6727** is well worth the search through a less-than-perfect sky. This is one of the brightest and most curious reflection nebulae in the sky: it shows as a fairly noticeable circular glow around two bright stars separated by a few arcminutes. The southwest section is illuminated by a seventh magnitude type A star, while the remaining section is lit by the unusual variable star TY Coronae Australis. TY Cor Aus varies between magnitudes 8.8 and 12.5, causing the nebula to change in apparent brightness. The area's real attraction lies 5′ southeast — **NGC 6729**. This comet-shaped nebula's "tail" points away from NGC 6726/7. NGC 6729 contains the faint nebular variable R Coronae Australis and behaves in much the same manner as the brighter Hubble's Variable Nebula in Monoceros. Careful observing over a long period will show that this nebula changes rather drastically in shape and brightness.

Moving north along the Milky Way, we come to Cygnus the Swan. Here lie four unique objects well worth sorting out from the countless background stars littering this region. The faint supernova remnant **NGC 6888**, sometimes called the Crescent Nebula, tops the list. As supernovae remnants go, this object doesn't even remotely resemble the Crab Nebula; rather, it appears as a miniature version of the Veil Nebula, measuring only 12′ across. In most telescopes, this object appears as nothing more than a few bright stars involved with a faint arc of nebulosity. However, observing it on a very dark night — or with a UHC filter — however,



IC 5076 in Cygnus, 90x

The Egg Nebula, IV Zwicky 67, 290x

NGC 7139 (left) and NGC 7142, 75x

IC 5146, the Cocoon Nebula, 56x

will show a ghostly oval ring of gray nebulosity. Inside this oval is the seventh-magnitude Wolf-Rayet star which excites the remnant to the point of luminosity.

Even more challenging is the low surface brightness object **IC 5146**, a combination emission/reflection region in northeastern Cygnus. Popularly known as the Cocoon Nebula, this faint circular patch of nebulosity conveniently lies inside an opaque dark nebula, making it a little easier to detect than it might otherwise be. IC 5146 has an unusual milky characteristic; many observers claim this is presumably because of the subtlety of its light. It contains several bright stars including a blazing central one, and is not difficult to spot in a 6-inch telescope with a nebular filter.

IC 5076, a lonely little reflection nebula in northern Cygnus, is one of those objects that is almost universally listed as "visually impossible." I tend to ignore those claims until I have a chance to check them out myself. Surprisingly, IC 5076 is not difficult at all in my 16-inch reflector and I even glimpsed a hint of detail. Appearing as a faint oval just touching a sixth-magnitude star, this 5′-long glow was distinctly brighter at its ends. About 100x seemed to be the best compromise between the nebula's faintness and the star's nearly overpowering brightness.

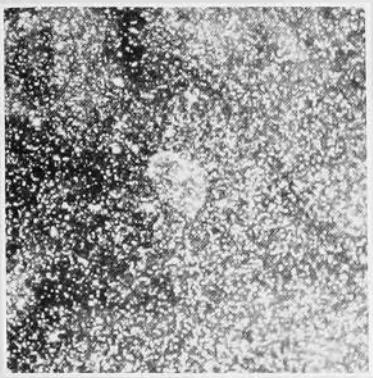
Our final object in Cygnus belongs to a very special class of object — bipolar nebulae. During the early 1970s, the peculiar nonstellar object **IV Zwicky 67** came under the scrutiny of infrared telescopes, rockets, and just about everything else that can make an astronomical observation. Initially detected as an infrared source, it was later discovered — in an amateur's 12-inch telescope — that this object is highly polarized. Affectionately dubbed the Egg Nebula because of its strange shape, IV Zwicky 67 instantly became an "in" object to observe. Recently, I observed this double nebula using my 16-inch scope and a gibbous Moon in the sky: the main body is about 5″ long with the components being 12th and 14th magnitude. The best way to look for this nebula is to plot it on a Tirion atlas and try scanning around using medium to high power. If the night is good, you'll see a fuzzy "star" which is actually the mysterious Egg Nebula.

Moving up to Cassiopeia, we find

Summer's Small Nebulae

Type	Designation	R.A. (2000) Dec.	Con	Mag.*	Spectrum*	Diameter	Vis	Bri	Col	Shp	Str
□R	van den Bergh 1	0h11.0m +58°46′	Cas	8.6	A	9′	—	2	VB	—	—
□ER	IC 59	0h56.7m +61°04′	Cas	2.5v	BO IVe	10′x5′	pF	2	B	—	—
□ER	IC 63	0h59.5m +60°49′	Cas	2.5v	BO IVe	10′x3′	pF	1	I	—	—
□E	Sharpless 2-188	1h30.6m +58°22′	Cas	—	—	10′x3′	—	1	R	Ir	F
□R	van den Bergh 8	2h51.6m +67°52′	Cas	8.5	AO	6′	—	1	B	—	—
□E	IC 1871	3h03.2m +60°29′	Cas	10	K3	4′	—	4	R	Ir	AF
□R	van den Bergh 16	3h28.3m +29°43′	Ari	9.1	A5	11′x5′	—	3	MB	—	—
□R	IC 4601	16h20.0m −20°02′	Sco	8.1	B9.5 V	20′x10′	—	3	VB	—	—
□R	IC 4603	16h25.6m −23°26′	Oph	7.9	B2 V	20′x10′	eF	3	MB	—	—
□ER	NGC 6188/6193	16h40.5m −48°47′	Ara	cluster	NGC 6193	20′x12′	F	2	—	—	—
□E	RCW 126	17h16.9m −36°21′	Sco	—	—	16′x4′	—	3	R	—	—
□R	van den Bergh 111	17h19.0m +06°05′	Oph	6.5	FOn	12′	—	3	B	—	—
□E	Sharpless 2-16	17h46.6m −29°18′	Sgr	cluster	Cr 347	12′	—	3	VR	Ir	AF
□R	IC 4684	18h09.1m −23°25′	Sgr	9.3	B9	3′x2′	—	3	B	—	—
□R	IC 4685	18h09.3m −23°59′	Sgr	7.3	07.5	10′x8′	—	3	—	—	—
□E	IC 1274	18h09.5m −23°44′	Sgr	9.9	B5	9′x8′	—	1	R	C	AF
□E	IC 1275	18h10.0m −23°50′	Sgr	8.0	B5 V	10′x6′	—	1	R	C	A
□E	NGC 6559	18h10.0m −24°06′	Sgr	9.8	B1	8′x5′	vF	1	R	Ir	AF
□E	Sharpless 2-35	18h15.9m −20°15′	Sgr	5.4	BO Ia	10′x7′	—	4	R	Ir	A
□R	NGC 6589	18h16.3m −19°48′	Sgr	9.4	B5	5′x4′	eF	1	MB	—	—
□R	NGC 6590/6595	18h17.0m −19°53′	Sgr	10.2	B6	4′x2′	pF	1	MB	—	—
□ER	IC 1283/1284	18h17.8m −19°40′	Sgr	7.6	B2	17′x15′	—	2	R	Ir	AF
□E	Sharpless 2-53	18h25.2m −13°13′	Sct	—	—	15′	—	3	—	Ir	AF
□R	van den Bergh 123	18h30.5m +01°11′	Ser	9.1	AO	10′x5′	—	3	MB	—	—
□E	Sharpless 2-64	18h31.6m −01°55′	Ser	—	—	20′x8′	—	2	R	Ir	AF
□E	Sharpless 2-55	18h32.2m −11°46′	Sct	—	—	20′	—	6	B	Ir	AF
□R	NGC 6726/6727	19h01.7m −36°53′	CrA	7.2	AO V	2′	F	—	—	—	—
□ER	NGC 6729	19h01.9m −36°57′	CrA	9.7v	F5pe	1′	—	—	—	—	—
□R	van den Bergh 126	19h27.1m +22°43′	Vul	8.3	A2	7′x5′	—	2	VB	—	—
□ER	Sharpless 2-82	19h30.3m +18°16′	Sge	10.7	BO	7′	—	3	—	Ir	A
□R	Minkowski 1-92	19h36.3m +29°33′	Cyg	—	—	0.2′	—	2	—	—	—
□E	NGC 6813	19h40.4m +27°18′	Vul	—	—	3′	vF	3	—	Ir	—
□E	Sharpless 2-88	19h46.0m +25°20′	Vul	—	B	18′x6′	—	3	R	Ir	AF
□E	Sharpless 2-84	19h49.0m +18°24′	Sge	8.0	B5.5 V	15′x3′l	—	3	R	Ir	AF
□E	Sharpless 2-90	19h49.3m +26°52′	Vul	—	—	8l′x3′	—	2	R	Ir	AF
□E	Sharpless 2-101	20h00.0m +35°17′	Cyg	9.0	07	16′x9′	—	2	R	Ir	AF
□E	Cederblad 174	20h02.8m +36°58′	Cyg	—	—	15′x5′	—	3	R	—	—
□R	van den Bergh 128	20h04.6m +32°15′	Cyg	5.6	B1.5 Ia	8′	—	4	I	—	—
□E	NGC 6888	20h12.0m +38°21′	Cyg	7.4	WN6	20′x10′	F	1	R	E	F
□E	Sharpless 2-104	20h17.8m +36°44′	Cyg	—	—	7′	—	2	R	C	AF
□R	NGC 6914a	20h24.3m +42°18′	Cyg	9.1	B7	6′	—	1	VB	—	—
□R	NGC 6914	20h24.7m +42°29′	Cyg	—	—	13′x12′	vF	—	—	—	—
□R	NGC 6914b	20h24.8m +42°23′	Cyg	8.7	B6	4′	—	1	VB	—	—
□R	van den Bergh 133	20h30.7m +36°56′	Cyg	6.2	F5 Iab	10′	—	2	MB	—	—
□E	Sharpless 2-112	20h33.9m +45°39′	Cyg	8.8	—	9′x7′	—	2	R	C	AF
□R	IC 5076	20h55.9m +47°25′	Cyg	5.7	B8 Ia	9′x6′	vF	1	VB	—	—
□E	NGC 6995	20h57.1m +31°13′	Cyg	—	—	12′	F	2	RB	Ir	F
□R	NGC 7023	21h01.8m +68°12′	Cep	6.8	B5e	18′	eF	1	B	Ir	AF
□E	IV Zwicky 67	21h02.5m +36°42′	Cyg	—	—	—	—	—	—	—	—
□R	van den Bergh 140	21h17.5m +58°36′	Cep	6.4	B2 IIIe	16′x13′	—	3	VB	—	—
□E	NGC 7076	21h26.3m +62°53′	Cep	—	—	2′	vF	—	—	—	—
□R	van den Bergh 142	21h37.1m +57°29′	Cep	8.8	B3	1′	—	3	B	—	—
□R	van den Bergh 143	21h37.1m +68°12′	Cep	8.3	AO	8′	—	2	VB	—	—
□R	van den Bergh 145	21h43.7m +48°55′	Cyg	7.4	F2	9′	—	3	MB	—	—
□R	NGC 7129/7133	21h44.4m +66°10′	Cep	cluster	NGC 7129	8′x7′	pF	1	B	—	—
□E	IC 5146	21h53.5m +47°16′	Cyg	10.0	B1	12′	pB	1	I	E	AF
□E	Cederblad 199	22h11.6m +58°45′	Cep	5.0	06 If	13′x5′	—	3	R	—	—
□R	van den Bergh 152	22h13.6m +70°18′	Cep	8.8	B9.5 V	12′x6′	—	1	B	—	—
□E	IC 1470	23h05.2m +60°15′	Cep	—	—	15′x1′	vF	2	—	C	AF
□E	NGC 7538	23h13.5m +61°31′	Cep	—	—	10′x5′	vF	1	R	E	AF
□E	NGC 7635	23h20.7m +61°12′	Cas	6.9	B2 IV	15′x8′	vF	1	R	Ir	F
□E	Cederblad 211	23h48.8m −15°17′	Aqr	6.4v	M7 IIIpev,B2	2′x1′	—	—	—	Ir	F
□R	van den Bergh 150	23h55.1m +76°37′	Cep	8.4	AO	11′	—	3	VB	—	—

Column 1: Object type: □E = emission nebula, □R = reflection nebula, □ER = complex nebulosity. **Column 2:** Designation in *Revised New General Catalogue*, by J. Sulentic and W. Tifft, *Index Catalogue* by J.L.E. Dreyer, and specialized catalogues compiled by astronomers Cederblad, Minkowski, Sharpless, van den Bergh, Zwicky, and Rodgers/Campbell/Whiteoak. **Column 3:** Coordinates for epoch 2000.0. **Column 4:** Constellation in which object lies. **Column 5:** Integrated magnitude of exciting star; v denotes variable. **Column 6:** Spectrum of exciting star. **Column 7:** Angular diameter in arcminutes. **Column 8:** Visibility; eF = extremely fiant, vF = very faint, F = faint, pF = pretty faint, pB = pretty bright. **Column 9:** Brightness; 1 = brightest, 6 = faintest, on red-sensitive photographic plates. **Column 10:** Color; VR = very red, R = red, I = intermediate, MB = moderately blue, B = blue, VB = very blue. **Column 11:** Shape: Ir = irregular, E = elliptical, C = circular. **Column 12:** Structure; A = amorphous, F = filamentary, AF = complex. Data from B.T. Lynds, Kitt Peak National Observatory, and volume 2 *Sky Catalogue 2000.0*, Sky Publishing Corp., 1985.



NGC 6888, the Crescent Nebula, is one of the sky's few visible supernova remnants. Photo by E.E. Barnard.

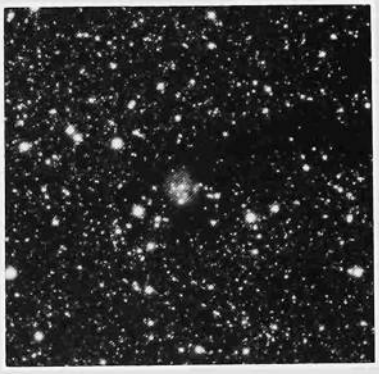
The constellation Cepheus holds van den Bergh 140, a diminutive reflection nebula. Photo by E.E. Barnard.

NGC 6995, the southern part of the eastern half of the Veil Nebula, is easily observed in medium backyard telescopes. Lick Observatory photo.

van den Bergh 143, also in Cepheus, is a relatively bright reflection nebula. Lick Observatory photo.

NGC 7023 is a large, circular reflection nebula in Cepheus. Lick Observatory photo.

IC 5146, the renowned Cocoon Nebula in Cygnus, lies at the end of a long tubular dark nebula. Lick Observatory photo.



several nice examples of small nebulae. A splendid combination of cluster and nebula together in one field is **NGC 7129** — a reflection object — and NGC 7142 — a small open cluster. Consisting of about two dozen stars, NGC 7142 is a nice grouping easily visible in nearly any telescope. Half a degree northward is the faint nebula 7129, which appears as a trapezoidal nebulosity with four bright stars involved.

More difficult to observe are two patches of emission/reflection nebulosity near the bright variable star Gamma (γ) Cassiopeiae. These are **IC 59** and **IC 63**, both large irregular areas of dust and ionized gas. These deep-sky targets might be much easier to spot if they weren't so close to Gamma, but if you carefully position the field of view so as not to include Gamma — or use enough magnification to eliminate it — this usually suffices. Use at least a 10-inch telescope on these objects, and try a UHC filter if they aren't easily visible.

* * *

The next time you have an opportunity to observe under a really dark sky, try finding a few of these elusive small nebulae. They are definitely challenging and will thoroughly test your ability to track down faint nebulosities. Use averted vision and remember that it doesn't matter how large or what type your telescope is — parts of the Veil, Cocoon, NGC 7023, IC 1470, and others have reportedly been observed with very small scopes. The important factor in observing these objects is patience — patience to wait for a superbly transparent night and patience to find subtle details in the eyepiece. Once you accept the patience necessary for such specialized observing, you've made a deal with the universe; in return, it will eventually show you most of what you look for.

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DSM Reviews

Sky Catalogue 2000.0
Volume 2: Double Stars, Variable Stars, and Nonstellar Objects
Alan Hirshfeld
and Roger W. Sinnott, eds.
385 pages, cloth $49.95, paper $29.95
Sky Publishing Corp. and Cambridge University Press (1985)

It is the more-or-less conscious editorial policy of *Deep Sky* magazine to provide the most up-to-date information about the objects discussed in each issue. Doing that has meant becoming familiar with the professional literature and attempting to keep up with developments in many fields. Thus the tables of "observables" like positions and magnitudes you see in these pages were not copied from venerable old works such as Becvar's *Atlas Catalogue* or Burnham's *Celestial Handbook*, but instead gleaned from recent tabulations in publications not readily accessible to most readers. How we have wished for a handy current reference to save us from heading to an observatory library!

First, a word about the older references. Much of the information in places like the *Celestial Handbook* was compiled from work done before World War II. Apart from star positions, not much else was calibrated on a standard system: only poor proper motions and a handful of double star orbits and redshifts for galaxies — and *no* magnitudes, colors, or MK spectral types. Now that has all changed, such that basic parameters for bright astronomical objects are well determined (okay: not *everything*, not for every object). The time is ripe, then, for a new catalogue of deep-sky objects that brings this data together in one place in a readily available form. Hirshfeld and Sinnott have done it. *Voila*! No more digging through back volumes of the *Astrophysical Journal*!

This new work probably could not have been prepared without computers. Indeed, if assembled by hand, this review would be premature, since the book would not yet be finished! Like its predecessor, *Sky Catalogue 2000.0 Volume 1*, it was compiled by interfacing and concatenating existing machine-readable catalogues of special classes of objects. If that were all there was to it, it would be easy to produce such a catalogue. But for Hirshfeld and Sinnott it was just the beginning — and that is good news for users of the catalogue.

Take, for example, the 8300-entry double star list. The fundamental reference source was the Lick Observatory *Index Catalogue of Double Stars* (IDS), specifically a magnetic tape version corrected and updated through 1975 by Charles Worley at the Naval Observatory in Washington. Some of the positions for pairs listed in the IDS are approximate. Hirshfeld and Sinnott programmed their computers to compare each position with precise values given in their star catalogue *Sky Cat 1*, inserting improved locations for hundreds of stars, and enabling them to add star names not given at all in the Lick IDS.

The IDS magnitudes are notorious — many of them are traceable to early 19th century observations not even close to contemporary magnitude scales. Wherever possible, Hirshfeld and Sinnott substituted photoelectric measures for individual components from recent work, or adjusted the data for close pairs so that the combined brightness would match that of standard values.

This painstaking line-by-line fixing-up had to be done throughout the catalogue. For double stars we find comments about colors and variability from early observers, doubtful observations and other historical background information. Nearly half the 2400 variable stars listed have additional information given in an extensive section of remarks. Nearly all the bright and dark nebulae have a concise description of their appearance on photographs. This is stuff not normally found in dry catalogues. The result is not an impenetrable list of numbers, but a cared-for catalogue where human foibles and the sometimes enigmatic universe converge in a Byzantine paradox.

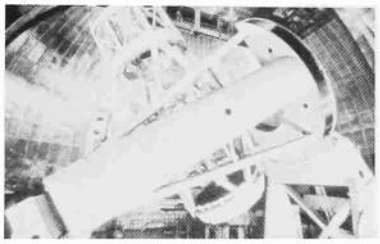
The thorough introductory discussion contains observing hints — like how to convert variable-star ephemerides from heliocentric to geocentric dates — and complete documentation of sources of the data and how it was manipulated for the catalogue. Apart from technical details, the introduction serves as a primer of current astronomical interest in each class of object, and gives the backyard observer a feeling for "what's out there," an appreciation of the significance of what one sees in a telescope. There is also a strong sense of historical continuity here, of generations of astronomers waiting for interesting pairs of stars to complete their orbits, of catalogued stars disappearing from view — a sense that this catalogue, despite the tremendous amount of work involved, is merely the latest byproduct of an even huger on-going custodial effort extending throughout the astronomical enterprise.

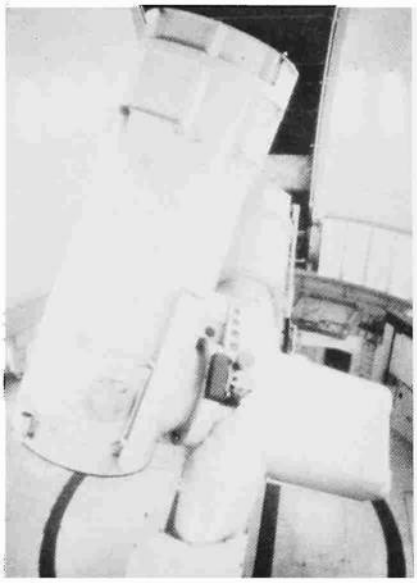
There are a number of unusually nice touches in the introduction. Included in the discussion on variables is a set of color-magnitude diagrams showing where different types of stars occur and at what stage in their evolution. Another fun one is a nomogram that allows you to figure the distance to galaxies by knowing the redshift velocity and "choosing your own" fashionable Hubble constant. Not many catalogues

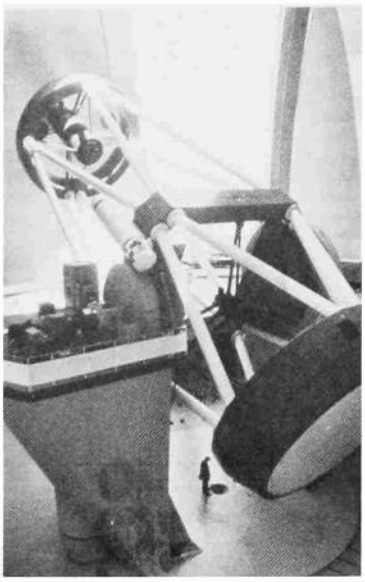
A section from SkyCat II: *finally: a handy, reliable source of data.*

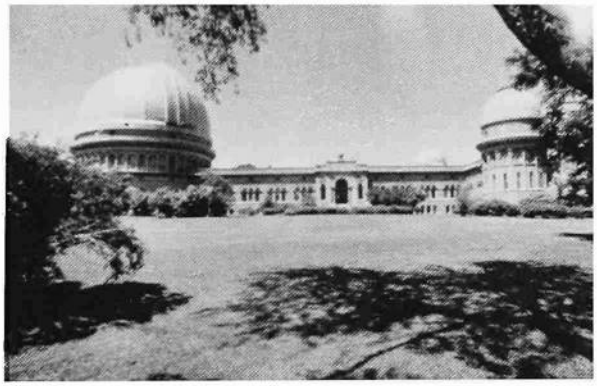
144-15.1		2 45.4	+42 33	Per	22	16.7			3b
141 -7.1		2 52.3	+50 36	Per	128	>16			4
136 +4.1		2 58.9	+64 30	Cas	185	>15.5			2b
138 +2.1	IC 289	3 10.3	+61 19	Cas	>34	12.3	-13	22	4+2
220-53.1	1360	3 33.3	-25 51	For	390		+42	27	3
159-15.1	IC 351	3 47.5	+35 03	Per	7	12.4	-9	15	2a
171-25.1		3 53.5	+19 28	Tau	40	13.9	-10		4
161-14.1	IC 2003	3 56.4	+33 52	Per	7	12.6	-16	18	2
144 +6.1	1501	4 07.0	+60 55	Cam	52	13.3	+36	39	3
165-15.1	1514	4 09.2	+30 47	Tau	>114	10	+60	25	3+2
147 +4.1		4 13.3	+56 57	Cam	12		-7		3
206-40.1	1535	4 14.2	-12 44	Eri	18/44	9.6	-3	19	4+2c
174-14.1		4 37.3	+25 03	Tau	20		-20		
166 -6.1		4 42.9	+36 07	Aur	12		-28	18	
215-30.1		5 03.2	-15 36	Lep	770	13.2	+18		3a
190-17.1		5 05.6	+10 42	Ori	>7	12.9	-23	17	2+4
167 -0.1		5 06.6	+39 08	Aur	60	16.6	+58		2b
173 -5.1		5 08.1	+30 48	Aur	132		+19		3
169 -0.1	IC 2120	5 18.2	+37 36	Aur	47		-8		2
215-24.1	IC 418	5 27.5	-12 42	Lep	12	10.7	+62	22	4

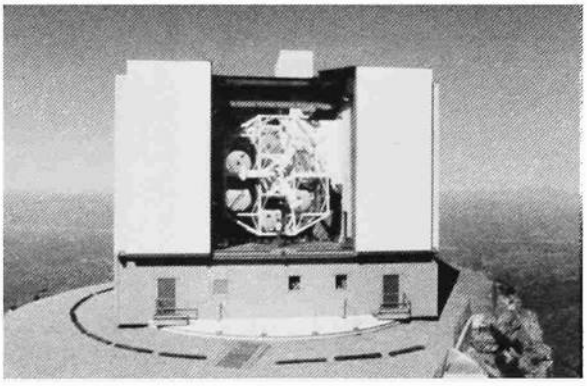
From the Astronomical Society of the Pacific's "Telescopes of the World:" *right:* **McDonald Observatory**'s modernistic 2.7-meter reflector; *far right*: the Soviet Union's mammoth **6-meter telescope**; *below right*: Arizona's combined 4.5-meter, futuristic "**MMT**"; *below left*: classic, elegant **Yerkes Observatory** in southern Wisconsin; *below*: Palomar's 5-meter historic workhorse, the **Hale telescope**.











give you miniature game boards to play with.

A curious, but fascinating feature is a Glossary of Selected Astronomical Names — a list of the florid ("Butterfly Cluster"), the mysterious ("Minkowski's Footprint"), and the unpronounceable ("Gyulbudaghian's Nebula") — all titles that have been applied to objects in the literature.

Finally, I must mention the reference bibliography. It consists of several hundred entries, divided into sections for each class of object. I consider myself pretty hep to the literature of "basic data," but I found some really useful ones here I had missed before. The references for bright nebulae were particularly illuminating (no pun intended).

One might find a few things to quibble about. It would have been convenient, for instance, to have HD numbers given for doubles as they are for variables. However, nearly-as-numerous ADS designations *are* given along with positions, of course. But let's face it: all the columns of figures are essential — nothing can be dispensed with — and there's only so much room on the page! Likewise, surface brightness magnitudes for galaxies are missing — a crucial problem for determining visibility — but the introduction explains how they are calculated and what they mean.

Though it is dwarfed by some professional catalogues, *Sky Catalogue 2000.0 Volume 2* contains a massive number of objects. The "box score"goes as follows:

11,700	double and multiple stars
476	visual binary stars
510	spectroscopic binary stars
2,325	variable stars
675	suspected variable stars
750	open star clusters
150	globular star clusters
285	bright nebulae
150	dark nebulae
565	planetary nebulae
3,112	galaxies
300	quasars
725	radio sources
73	X-ray sources

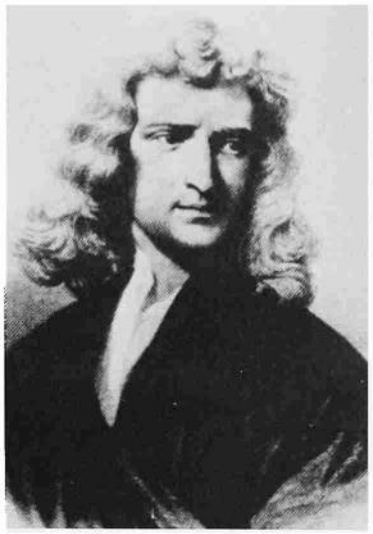
for a grand total of (pass the envelope, please): 21,796 entries.

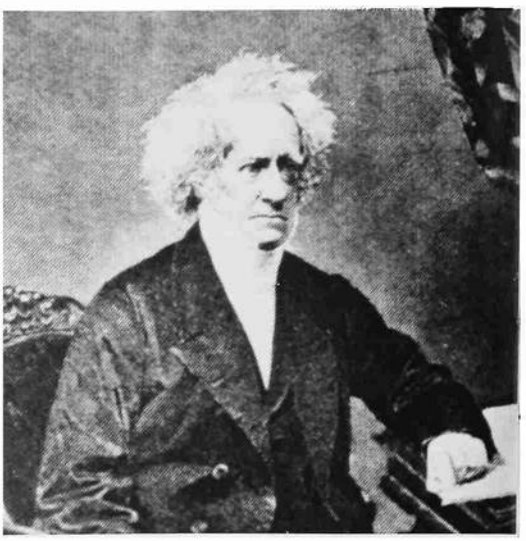
This whopping number of objects provides plenty of information about plenty of objects. Especially laudable features are the inclusion of a small number of dark nebulae (most catalogues ignore these altogether), and excellent lists of quasars and radio and X-ray sources.

A final word about errors. In any work of this sort erors inevitabbly creap in. Yet far fewer mistakes occur from interfacing files than would appear if the files had been created by hand. I estimate from a rough count there are something over 1½ million digits in the book; a few thousand errors (0.1%) might be expected. Ask any astronomer if he can quote the distance to the Hyades to the same precision!
— *Brian Skiff.*

Astronomers of the Past
Telescopes of the World
Astronomical Society of the Pacific (1984)

Two slide sets from the Astronomical Society of the Pacific (1290 24th Ave., San Francisco, CA 94122), released in 1984, focus on historical hallmarks in





From the ASP's "Astronomers of the Past:" *above*: Isaac Newton (1642-1727), a Professor of Mathematics at Cambridge, revolutionized astronomy and science in general; *above center*: William Herschel (1738 -1822) discovered Uranus and was the greatest deep-sky observer of all time; *above right*: William's son John Herschel (1792-1871) accomplished in the southern sky what his father did in the north; *far right*: William Huggins (1824-1910) pioneered astronomical spectroscopy; *right*: William Parsons (1800-1867), the Third Earl of Rosse, named the Crab and other nebulae.

astronomy — celebrated astronomers of the past and some of the world's great telescopes. For anyone interested in the history or people involved with astronomy, these sets are a gold mine of images.

The Astronomer's Set ($37.95) features 50 significant contributors to our knowledge of the universe — many in familiar poses: E.E. Barnard with the Lick Observatory's 36-inch refractor; Albert Einstein scrawling on a blackboard; and Edwin Hubble leaning on Palomar's 1.2-meter Schmidt. There is a fine selection of early astronomers' portraits including Tycho Brahe, Galileo, Newton, Kepler, William and John Herschel, and Nicholas Copernicus.

But don't get me wrong: The most interesting part of this slide set is not the well-known image of Hubble at Palomar or Barnard at Lick — these photos are published *everywhere.* What intrigued me were rarer images: A *circa* 1860 photograph of William Parsons, the Third Earl of Rosse; Englishman William Huggins with his unkempt salt-and-pepper beard; Walter Baade, Milton Humason, and Vesto M. Slipher.

Unlike the black-and-white astronomer's set, slides of the great telescopes ($41.95) are largely color. Here we travel the world, stopping at major optical observatories in the United States, Chile, Australia, the Soviet Union, and the Canary Islands. Also included are special installations — Sac Peak solar observatory in New Mexico, the transit telescope in Washington — and major radio dishes including Green Bank, West Virginia; Jodrell Bank, England; Parkes, Australia; and the Westerbork and VLA arrays in Holland and the United States.

There is something here for everyone. Yerkes, the classic observatory in Wisconsin, and the MMT on Mount Hopkins, Arizona, offer a dramatic contrast. If the photo of the 5-meter Hale telescope doesn't grab you with its awe-inspiring proportions, then you may be unreachable.

I am happy to see the ASP offering such instructional and enjoyable slide sets. Although they aren't cheap, they're worth the expense if you're a devotee of astronomical history or instrumentation. *David J. Eicher.*

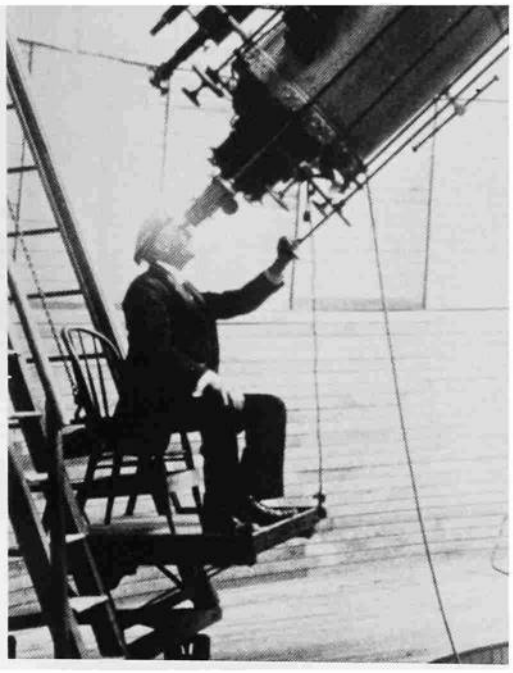
Colours of the Stars
David Malin and Paul Murdin
198 pages, cloth $29.95
Cambridge University Press (1984)

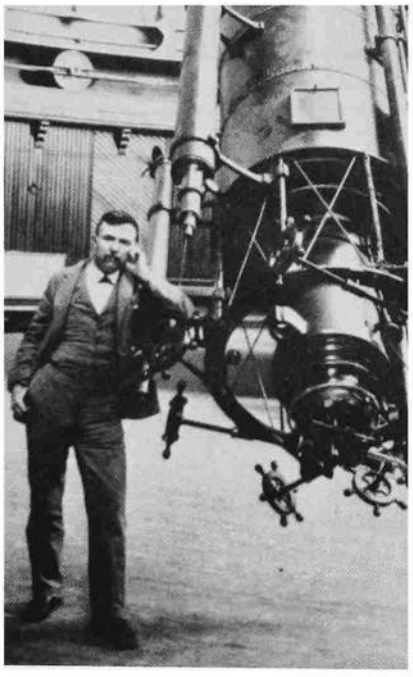
"*The sky is the daily bread of the eyes.*" — Ralph Waldo Emerson, *Journal*, 1843.

In high school I was involved with an astronomy club, most of whose members were legally blind. To be sure, all were at least partially sighted, though in some cases it was by no means secure: they might become sightless any day. But they enjoyed looking at the night sky and through telescopes, acutely aware — despite their youth — that these tenuous views might be their last.

Those of us more fortunate than they could afford to become more appreciative of our vision in what must be the most visually-oriented science. A wonderful vehicle for doing that has been assembled by a couple of guys who are ahead of most of us, two people who obviously enjoy the sky.

This book is really about astrophysics: the course of stellar evolution, the origin





above: **Percival Lowell** (1855-1916) a prolific observer; *above center*: **Edwin Emerson Barnard** (1857-1923) the photographer and cataloguer of dark nebulae; *above right*: **Edwin P. Hubble** (1889-1953) revolutionized cosmology by discovering the nature of galaxies; *far right*: **Harlow Shapley** (1885-1972) was an expert on star clusters and variable stars; *right*: **Albert Einstein** (1879-1955).

of nebular emission lines, the differences in stellar populations among galaxies. But we find out about these subjects in an easy way by using colors: how colors show the temperatures and evolutionary states of stars, what colors appear in various types of nebulae, how color gradients across galaxies indicate changes in the ages and chemical compositions of the component stars.

Along the way we get a lot of history of astrophotography, discussions about the color sensitivity of film emulsions and the perceptions of the eye *vs.* reality. Almost inadvertently the authors provide excellent introductory discussions about two basic astronomical tools — photometry and spectroscopy. An example of how these work together is a section comparing the color impressions of stars by early observers with photometric B-V "colors" and spectral types for the same objects. Can we conclude from these comparisons that F.G.W. Struve was color-blind to red?

An entire chapter and two appendices are devoted to the process of photography. Included is advice on films and filters for both direct color exposures and making three-color monochromatic separations. Darkroom techniques such as making unsharp masks and combining black and white separations into a true color print are outlined, including a list of materials. Photographers are given the basics and then encouraged to experiment, since specifics can't be given for everyone's setup, nor for every photograph in the book.

Four chapters cover nebulae: "The Dust Clouds of Sagittarius" (mostly Barnard dark nebulae), "Nebulae from Stars" (planetaries, supernovae remnants), "Stars from Nebulae" (young, star-forming HII regions), and "Starlight from Dust" (scattering processes and reflection nebulae). Another chapter outlines the colors of galaxies — mostly nearby ones, full of billowing pink HII regions and luminous blue stars and clusters.

The writing is lucid, full of historical surprises and anecdotal humor. The technical subject matter is treated especially well — just enough so to keep you from being confused — and is on the level of such works as Bok's *The Milky Way*. That is, the writing is authoritative, yet has an aesthetic orientation thoughtful of visual observers. A thorough bibliography is included.

But the pictures! For a book as reasonably priced as this one, the publisher did a remarkably good job of reproducing so many difficult color photos. There are lots of pictures of every type of deep-sky object, naturally emphasizing planetary, emission, and reflection nebulae (11 shots of the Orion Nebula!).

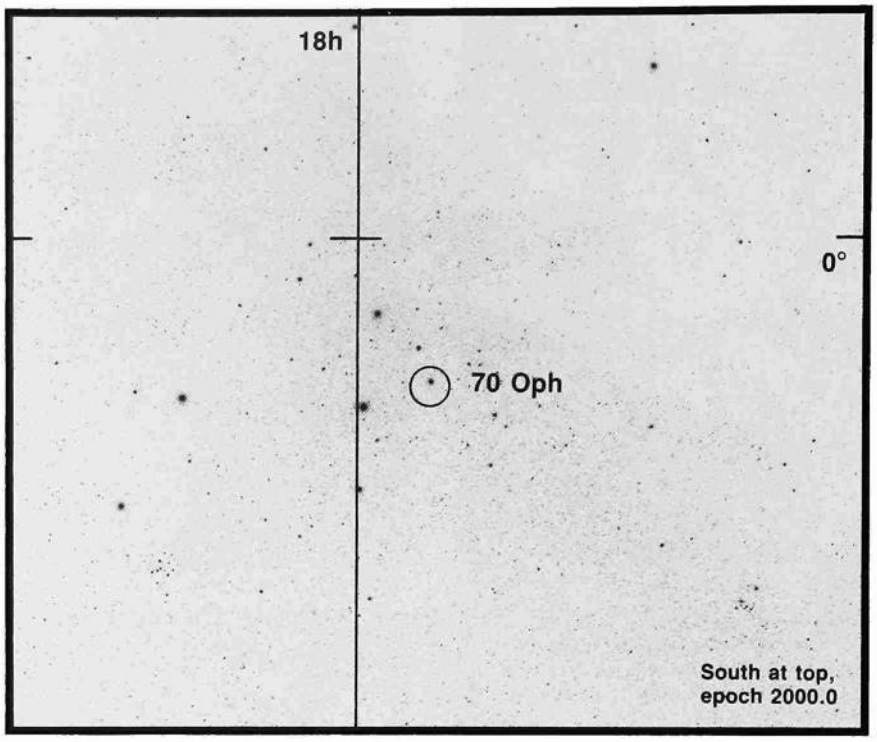
It might be too much to suggest that there is enough here to make it usable as a textbook, although a teacher possessed of unorthodox methods might try it. There is no solar system astronomy, of course. There is enough for readers to get a glimpse of astronomical research techniques, and enough to provide amateurs with the wherewithal to explain what's in the eyepiece. For all of us, this book contains more than enough to show what it is that inspires astronomers to explore the universe. — *Brian Skiff.*

DSM Reports

The Need to Measure Double Stars

by Robert W. Argyle

Few readers of this magazine need encouragement to observe double stars. The variety of colors and separations found make one of the finest beauties of the night sky — and when the two stars form a binary system there may be the added interest of watching the suns swing around each other over the years.



Lick Observatory

70 Ophiuchi

Date	P.A.	Sep.
1975.64	5.5°	2.30″
1976.55	356.9°	2.38″
1977.60	346.4°	2.05″
1978.60	337.4°	2.29″
1979.65	327.7°	2.41″
1980.60	321.6°	2.55″

The finest short-period binaries in the northern sky for small telescopes are ξ UMa and 70 Oph, which have periods of 60 years and 88 years, respectively. At present, the components of ξ UMa are beginning to close in after reaching their greatest apparent separation (3.1″ in 1974). 70 Oph reached maximum separation of 2.3″ in 1982; minimum separation (1.5″) comes in 1990. The table (giving measurements made by Domenico Geller of Italy with an 11-cm Zeiss refractor and a filar micrometer) shows 70 Oph's rapid motion — more than 40° in five years.

These two double stars belong to the class of binaries whose orbits are regarded as "definitive," the appellation given by William Finsen and Charles Worley in 1970. But even after more than 150 years of the reliable micrometric measurement, less than a thousand binaries have any orbit computed for them! Finsen and Worley's catalogue includes 795 orbits for 696 systems of which only some 8% are definitively known. Compared to an estimated 40,000 true binary systems out of the 73,000 known pairs of stars, this is a drop in the ocean of knowledge about these objects.

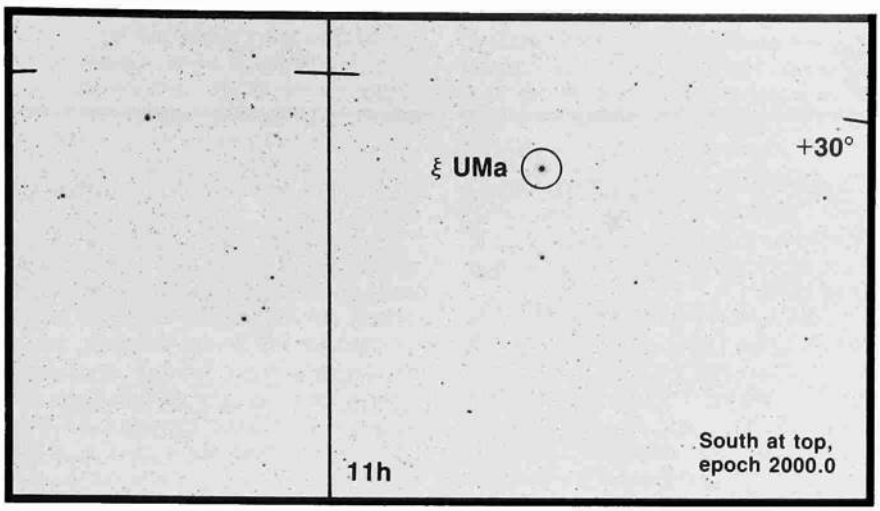
Not surprisingly, modern double-star astronomers concentrate on the close pairs where short periods are most likely to occur and information about the stellar masses can be derived in a fairly short time. Even so, investigators always depend on having sufficient observations for orbital analysis — and the ultimate burden lies on the shoulders of the observer at the telescope.

Classical micrometric techniques are still being used by a small number of very experienced observers, principally Paul Couteau and Paul Muller at Nice France; Charles Worley and Richard Walker at U.S.N.O.; and Wulff Heintz at Sproul in the United States. The French observers are in the process of reexamining a large number of *Bonner Durchmusterung* stars in the northern hemisphere for new pairs and, in the course of their work, they have discovered more than 2,100 such objects — many of which are close and difficult.

But what about the many wider pairs found in the Lick *Index Catalogue of Double Stars*? A cursory examination shows that many have been very scantily observed, some passing unexamined for 50 years or more. Here is an excellent opportunity for observers with 8-inch and larger telescopes to make a valuable contribution to double-star astronomy.

Which stars should be examined? The catalogues of F.G.W. Struve, Otto Struve, R.G. Aitken, S.W. Burnham, W.J. Hussey, and G.P. Kuiper in the north, and W.H. van den Bos, R.T.A. Innes, R.A. Rossiter, and W. Finsen in the south are generally well covered by the professional observers. The catalogues of R. Jonckheere, T.H.E.C. Espin, and W. Milburn are badly neglected, however. Just as an exercise, I examined the first two hours of right ascension in the Lick catalogue looking for all the pairs found by Espin

Pair	R.A. (2000) Dec.	Mags.	Sep.	P.A.	Date
Espin 1199	0h20.1m +45°48′	10, 0, 10.4	2.9″	16°	1914
Espin 42	0h20.2m +54°04′	8.8, 9.8	10.3″	192°	1902
			9.2″	193°	1936
Espin 936	0h37m +55°31′	10.7, 10.7	6.9″	270°	1904
			8.1″	264°	1911
Espin 1867AB	0h43.6m +61°15′	10.1, 10.3	5.4″	285°	1904
			6.4″	270°	1923
Espin 617	1h32.9m +54°42′	10.1, 10.1	3.3″	305°	1908
			2.6″	307°	1934



and given a number by him.

The two figures show the results. The first represents the number of pairs whose primary lies between magnitude 6.5 and 13.5 in steps of half a magnitude. The other figure shows the separations, ranging from 0.0″ to 15.0″ in 1″ steps. (The rather sudden cut off at magnitude 11.5 in the first figure represents instrumental limits.) The figures represent 302 Espin pairs. Very few of these pairs have been measured more than once and the few that did exhibit motion have not been measured for many years. Examples of the latter stars are given in the second table.

You'll notice that while many of Espin's pairs are difficult for small telescopes, a reasonable number lie within the grasp of a 12-inch reflector. The magnitudes quoted in the Lick catalogue for the primary component represent the BD magnitude (where applicable) and that of the secondary is presumably an estimate by the discoverer. In either case, the magnitudes may well need to be revised.

Here in England, the Webb Society has had a Double Star Section since 1967 but only over the last three or four years have we been making serious measurements of double stars with filar and diffraction-image micrometers. Colin Pither has described the operation of the diffraction grating micrometers in *Sky & Telescope* (see bibliography). Filar micrometers manufactured by Ron Darbinian of California have been purchased by several members of the Section who are putting them to good use. You'll find more details of the techniques of observing in the books by Aitken (old now, but good for background), Couteau (recent and highly recommended), and Worley, as well as in the Section's own *Handbook*.

Our three main programs are:

(a) Examining the wider pairs in the F.G.W. Struve (Σ) catalogue where rectilinear or binary motion has been established and also a small number of the brighter binaries (i.e., γ Vir, ξ UMa, and 70 Oph).

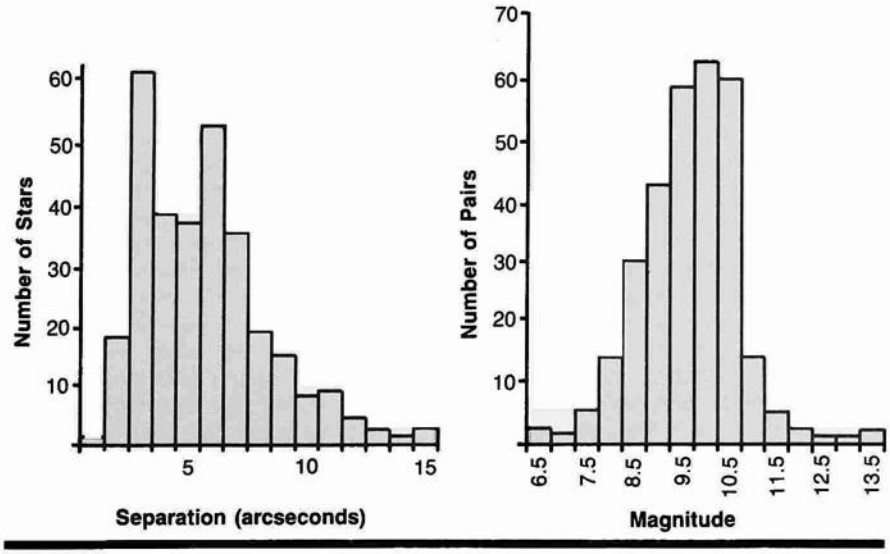
(b) A remeasurement of all the pairs in the Otto Struve (OΣΣ) catalogue which Dembrowski first measured accurately in the 1870s.

(c) A measurement by Domenico Gellera of double stars in the catalogue of M.A. Pourteau in the 7th hour of right ascension, using a homemade x-y measuring machine and Palomar *Sky Survey* prints. This will soon be published as Webb Society Double Star Section *Circular* No. 2.

Over the last year or so I have been in touch with Pierre Durand of the Societe Astronomique de France. He has formed a Double Star Section within the S.A.F which has Dr. Paul Baize as its honorary president.

Thus, the outlook for amateur double-star astronomy is brighter than it has been for many years. However — and this is a plea! — we need many more observers. The work is admittedly unglamorous (though quite enjoyable) and the would-be dobule-star observer needs skill, enthusiasm, dedication, and a certain amount of dogged persistence. Also, anyone who's never used a micrometer before needs training before they can expect usable results. But the newcomer who emerges undeterred through these preliminary hardships will certainly be welcomed into the small band of observers for whom the measurement of double stars is a constant delight.

"Luonnotar,"
Lower Horsebridge,
Hailsham,
Sussex,
England BN27 4DN



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(The Worley articles are available from Sky Publishing in the form of a single pamphlet called *Visual Observing of Double Stars*.)

Double Stars

A Column on Columns, or, The Glories of Ophiuchus in the Summer

by Glenn F. Chaple, Jr.

I recently received a letter from one of my most loyal readers and it was so nice, I just had to share it with you. It goes:

Dear Glenn,

I just finished reading your double star column in the latest issue of Deep Sky. *As always, it was a masterpiece — the work of a true genius. Your writing was flawless. How do you put together such a high quality product season after season? Your editor should certainly give you a big fat pay raise!*

Love, Mom

P.S. Remember to wear your woolen snuggies when you go out on those cold nights. I don't want my baby to get the sniffles.

My Mom. What a peach! But how do I produce this seasonal "masterpiece"? Let's take a behind-the-scenes look, going way back to the initial planning stages.

Each September or thereabouts, I prepare a tentative roster of articles for the coming year. On a sheet of paper, I list the four seasons in a column. Using a planisphere, I then note which constellations are well-placed for observing at approximately 8 to 10 p.m. during mid-season. (10 p.m. is for the summer months when, thanks to that insane invention called Daylight Saving Time, it gets dark late.)

I consult a record of past columns to prevent my selecting constellations that may have been featured during recent years. I jot my final choices down next to the appropriate constellations. If I have a good idea which double stars I'd like to feature, I list them, too. This planning roster, which takes less than an hour to prepare, is by no means rock-solid. Readers' comments or my own experiences while observing may call for last-minute changes.

Work on the actual article begins three to four months ahead of the publication date — for example, this is being written during the last few days of February. According to my planning roster, Ophiuchus is the target constellation for summer 1985. I used this constellation a few years ago, but wrote only about the rapid binary 70 Ophiuchi. There are still plenty of pairs for me to describe, but which ones? (None are listed on the planning roster.) Shall I produce a general overview of Ophiuchus to include its major double stars, or should I focus in-depth on one small area?

I open *Norton's Star Atlas* to the map that includes Ophiuchus and place it beside a list of all the pairs I've seen in this constellation. I quickly discover that three objects — 36, 39, and h589 — cluster in the southern part of Ophiuchus around the star θ. (*Norton's* doesn't show h589, but its coordinates place it near θ.) The θ Ophiuchi region looks promising, but are there any other double stars there?

I turn to volume 2 of *Burnham's Celestial Handbook* where I find there are indeed more pairs near θ. Judging by their magnitudes and separations, some are too difficult for the typical backyard telescope. Others just don't look interesting. HI 35 (a William Herschel pair plotted as 38 Ophiuchi in *Norton's*), ξ (= 40), and β127 look like good prospects. *Norton's* shows the location of two additional pairs. Hn 134, according to *Burnham's* data, is too difficult. β129 might be a good test object. So what do we have? It looks like 36, 38, 39, and ξ Ophiuchi, plus h589, β127, and β129. I could consult the *Lick Catalogue* for even more pairs, but this list is pretty good. It's time to write an article!

Writers soon learn to open an article with an introductory paragraph that's both interesting and informative. It's critical to have an eye-catching lead sentence. Like: "If you don't read this column, I'm gonna personally punch you in the nose!" I can then elaborate on the anatomical structure of the human nose and what happens when it comes in contact with a rapidly-accelerating fist. Then I'll close with a good transitional sentence like: "Speaking of bloody noses, let's look at some double stars near θ Ophiuchi."

When I write about several double stars, I often arrange them so that the easiest ones come first. So 39 Ophiuchi, with magnitude 5½ and 7 component stars placed a comfortable 11″ apart, gets the lead-off slot. Now what can I say about this duo? I could begin by pointing out that it lies a little over one degree northwest of θ, and that *Norton's* identifies it by the Greek-letter designation o. Notes in *Burnham's* mention a "color contrast," and my own records show that the pair looked "yellowish and green or blue" to me. Since this observation came during my early days as an amateur astronomer, the colors must have been strong to have been detected by my inexperienced eyes.

The next pair will be 36 Ophiuchi. It's comprised of a pair of 5½ magnitude suns (should produce a nice cat's eyes effect) set 4.5″ apart. This pair was a bit tight for my 3-inch reflector, so I'll recommend high powers and good seeing. My notes say nothing about the colors, but *Burnham's* assigns a K-type spectrum to both stars (and to a 7th magnitude physically bound companion situated 12 arcminutes away). I'll suggest, therefore, that the observer look for a golden yellow coloring in all three system members.

According to several of my sources, the closest pair form a binary system with an estimated period of around 550 years. This information will also be worked into my text. Since HI 35 (= 38 Oph) is in the same field as 39, a scant half degree eastward, I'll attack it next. I've never seen this pair, and disparities in its listed magnitudes (6½ and 9 in *Burnham's*, 6½ and 11 in *Webb's Celestial Objects for Common Telescopes*, and 7.1 and 8.6 in the *Lick Catalogue*) pose a problem. Obviously, I should observe this pair and report my findings. But I won't. My readers deserve better than to be spoon-fed all the time. Therefore, I'll ask for magnitude estimates of 38 Ophiuchi from those who take the time to make an observation. I can then report the results, plus my own estimates, in a future column.

Next on the agenda is h589, whose magnitude 7½ and 8 suns fell to my 3-inch reflector a few summers ago. My notes call this 10″ double a "pretty little pair." Pretty unoriginal! I'll settle with a comment that it's located three degrees west of θ Ophiuchi.

Now comes the tough stuff. ξ Ophiuchi, whose 9th magnitude secondary lies just 3.7″ from a primary that's 60 times brighter, and β129, whose components, though more equal, are only 0.9″ apart, will be recommended for the big-scope owners. And compared to these stars, β127 is a piece of cake. I'll challenge owners of 4-inch scopes to find and split this one.

To complete my column, I'll wrap things up with a good finishing statement: "Observe these double stars, or plan to have your nose rearranged!" Then I'll add the "Double Takes" section after browsing through my mail and reporting any interesting notes. I'll also need to produce a data list to supplement the main articles.

Once these are completed, everything goes in the mail to DSM

editor Dave Eicher (*after* it has been photocopied — several years ago, the Pony Express lost one of my articles). It is here that all the grammatical errors and spelling mistakes I so studiously avoided are reinserted into the text (just kiddin', Dave!).

Well, Mom, that's how your little boy does it. Now if you'll excuse me, I have to draft a letter demanding a 300% pay raise for my DSM work.

* * *

Double Takes: Looking for an informative, up-to-date catalog of double stars? Try the new volume 2 of *Sky Catalogue 2000.0*, edited by Alan Hirschfeld and Roger Sinnott. (See review on page 26.) Recently released by Cambridge University Press and Sky Publishing, this valuable work contains data on all double and multiple stars with a combined magnitude of 8.0 or brighter — over 8300 systems in all.

That's not all, either. A supplementary section provides current and future separation and P.A. for over 500 visual binaries. And there's more! Additional lists describe over 2400 variable stars, 750 open and 150 globular clusters, several hundred bright, dark, and planetary nebulae, and 3110 galaxies. All this for $29.95 (soft-cover) or $49.95 (hard-bound) — a bargain of truly astronomical proportions.

82 South Harbor Road
Townsend, MA 01469

Variable Stars

Summer's Milky Way Variables

by David H. Levy

"Hark to the voice of experience," my Dad loved to tell me with a smile, "Learn its ways and be wise." He wouldn't have been surprised just how well his words applied to the observation of variable stars. You might think that finding and estimating the brightness of variables is a simple and straightforward process that anybody with at least a few neurons could accomplish easily. It is simple — in theory. It's only when you actually begin to look for a star that you run into problems that experience alone will solve.

Our first star, χ **Cygni**, offers a good example. At its brightest, this star in the neck of Cygnus, is bright enough to be seen with binoculars — or even the unaided eye on a good night.

That's fine when the star is bright. The story changes when the star gradually fades and merges to join large numbers of Milky Way background stars. At seventh or eighth magnitude, χ Cygni is still easy to pick out. Even at ninth magnitude you don't run into much of a problem. But when the star drops to tenth or eleventh it gets difficult. One night in August of 1971 I tried to find χ Cyg when I knew it was faint. Arriving at the star toward what I had hoped would be the end of a fine observing session, I thought I'd spend a few minutes finding, and even fewer estimating, what for me would be a new star. *Two hours later* I still hadn't found it! Frustrated and annoyed, I kept on looking until I was finally satisfied that a slightly reddish 12.8 magnitude point of light was the star I had been seeking.

Why had it taken so long? First, I was a neophyte variable star observer with a lot of undefined aims and not too much experience. I thought I could simply look and the stars would beat a path to my eyepiece. Guess what? It doesn't happen that way — neither with variables nor with any other worthwhile branch of observing.

Take a close look at the charts supplied with this column. The "a" chart, designed for binocular use, shows a good deal of central Cygnus, with γ near the upper left, δ at the top, and β at lower right. Beside some of the stars are two-digit magnitude indicators; γ Cygni, for instance, has a "23" which indicates that is magnitude is 2.3. (The decimal points are left out to avoid confusion with star points.) Use the "a" chart with binoculars; it has north at the top for a view that coincides with the upright field binoculars have.

Use only enough optical aid to see the variable clearly. If you use too much, estimating becomes cumbersome and less accurate. It χ is so bright that you can see it without any optical aid, then try to estimate it that way using appropriate stars nearby. Choose one slightly brighter and another slightly fainter than χ, and estimate by steps. Say that χ is noticeably fainter than the 6.6 star and much brighter than the nearby 7.3 star. Then it is probably 6.8. With more experience you will soon gain confidence in your ability to estimate.

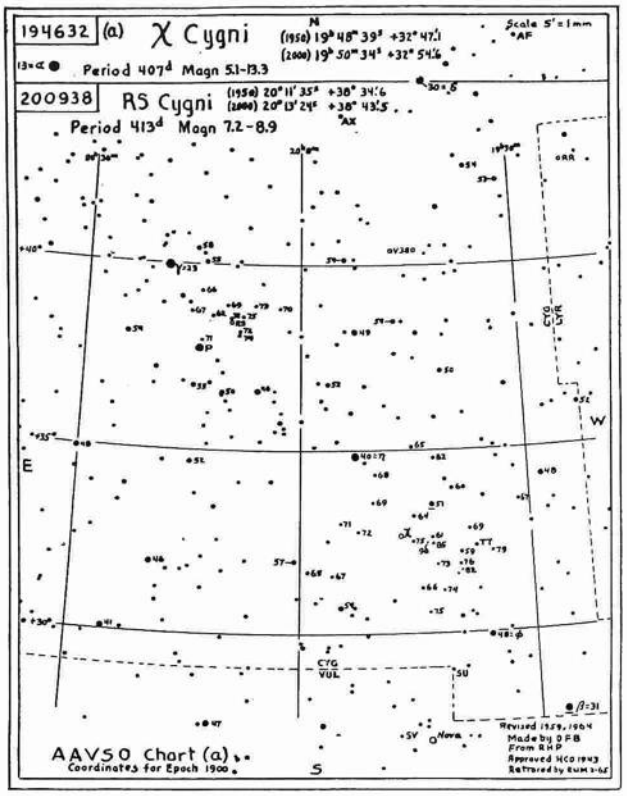
The "b" chart is designed for use with small telescopes, as you can tell by the inverted field. All these "b" charts used by the American Association of Variable Star Observers (AAVSO) are based on the old *Bonner Durchmusterung* atlas that appeared in the middle of the nineteenth century, and include stars well into the 11th magnitude range. A small citybound telescope works well with such a chart. If χ is fainter than the 11.4 star on this chart and you cannot see it, then simply write 11.4 as your estimate.

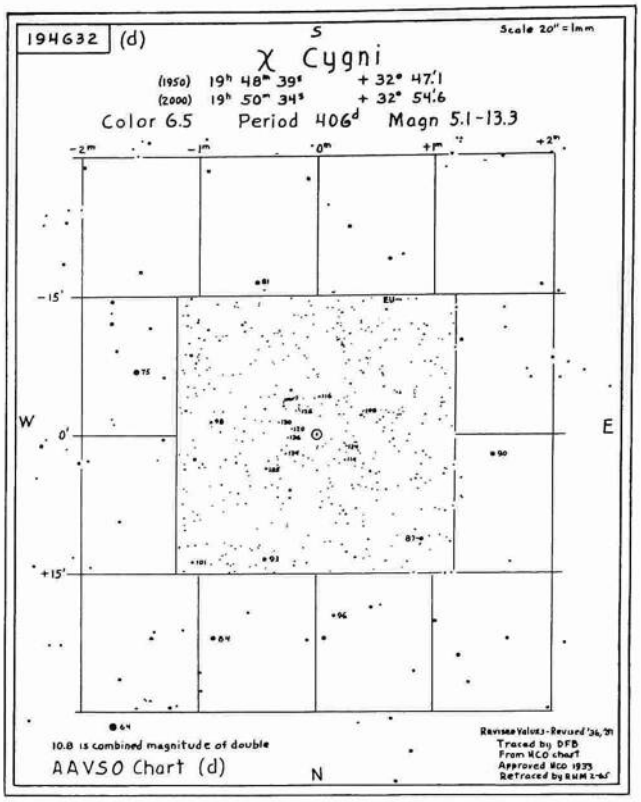
If the star is fainter still, then you must use the "d" chart that plots stars down to 13.6 magnitude and is all you need with a 6- or 8-inch telescope. But notice how densely crowded the starfield is! If χ Cygni is faint then you may have trouble finding it — I sure did, anyway. If your telescope has more light-gathering power, you may need the still fainter stars that are plotted on an "e" chart available from the AAVSO.

200938 **RS Cygni**. On the same "a" chart as χ lies a bright variable named RS Cygni, a star whose prominent red color makes it easy to find. The star's nominal period is unusually long — 413 days — but its behavior is characteristic of the bright semi-regular stars about which you have read so much in these columns. With its entire range brighter than 9th magnitude, RS Cygni is fun to watch and fun just to look at. After your deep-sky friends have entertained you with their galaxies, you can toss this beautiful star right back at them. Just remember that red stars are hard to estimate unless you look at them in quick glances, rather than in prolonged stares.

Cygnus has over 1500 known variables, and a look through the AAVSO chart catalog will show some old friends. **R** and **Z Cygni** are easily found Mira-type stars. There is another easily-found semi-regular star east of Deneb and south of M39, called 213244 **W Cygni**. With a range of 5.1 to 7.2 and a period of roughly 131 days, this star is easy to find, and a good selection of comp stars make it fairly easy to estimate. Since the star's period is so long and its variation so slight, there's

AAVSO#	Name	Period	Type	Range
194632	χ Cygni	407d	Mira	5.1-13.3
200938	RS Cygni	413d	semi-reg	7.2-8.9
213244	W Cygni	131d	semi-reg	5.1-7.2
213843	SS Cygni		U Gem	8.1-12.2
184*205*	R Scuti	146d?		4.5-9.0
194*929*	RR Sgr	33d	Mira	6.6-13.3
191*033*	RY Sgr	irreg	R CrB	6.0-14.0


194632 (a) χ Cygni
(1950) 19h 48m 39s +32° 47.1
(2000) 19h 50m 34s +32° 54.6
Period 407d Magn 5.1-13.3
200938 RS Cygni
(1950) 20h 11' 35s +38° 34.6
(2000) 20h 13' 24s +38° 43.5
Period 413d Magn 7.2-8.9
Scale 5' = 1mm
AAVSO Chart (a)
Coordinates for Epoch 1900.
Revised 1959, 1964
Made by DFB
From RHP
Approved HCO 1943
Retraced by RHM 2-62


194632 (d)
χ Cygni
(1950) 19h 48m 39s + 32° 47.1
(2000) 19h 50m 34s + 32° 54.6
Color 6.5 Period 406d Magn 5.1-13.3
Scale 20' = 1mm
10.8 is combined magnitude of double
AAVSO Chart (d)
Revised Values - Revised '34, '39
Traced by DFB
From HCO chart
Approved HCO 1935
Retraced by RHM 2-62

Chi (χ) Cygni is a tough variable to observe — sometimes! Ranging from 5th magnitude to 13th, it may be invisible in all but large telescopes when you look for it. Reproduced by special permission from AAVSO director J.A. Mattei.

no point in estimating it more than once or twice a month.

But nearby is a variable that merits watching every night. 213843 **SS Cygni** is a star that has been mentioned in this column many times. But since summer is here again, SS Cyg will be well placed to form an important part of your observing program. Since its sudden increases in brightness are not exactly predictable, the star could add an extra measure of excitement to your observing.

Before we move southward along the Milky Way into Sagittarius, which has over 2400 listed variables, let's explore one interesting variable in Scutum. 184*205* **R Scuti** is an active and interesting variable that lies near M11. Its variation, from 5th to 9th magnitude, is easily followed through a pair of binoculars.

And now for two variables in Sagittarius. **RR Sgr**, 194*929*, is a standard Mira star with a range of almost 7 magnitudes and a period of 11 months. Stars like RR need watching every 2 weeks as they meander through their cycles, and after observing RR for a while you'll come to know it as a reliable friend. In their stately cycles lies the beauty of the Mira stars.

Nearby is **RY Sgr**, 191*033*, a star of a different color and certainly different behavior. RY is a "reverse nova" like its more northerly twin R Coronae Borealis. It normally stays at its 6th magnitude maximum, but at unpredictable intervals of months or years, it will suddenly plunge by eight full magnitudes to a dim 14th magnitude minimum, and then slowly climb back up. Enjoy the mystery of RY Sgr, for its surprising ways may add a good deal of zest to your observing program.

We have considered a few interesting variables for the summer. In other issues of *Deep Sky* you will find more variables to add to your observing program. For a complete listing, however, I suggest you join the American Association of Variable Star Observers (187 Concord Avenue, Cambridge, MA 02138).

By now you must have noticed that variable stars have strange names. Some have single letters like R and S, others have double letters like SS, and still other use only numbers. Why? One of the strangest systems of nomenclature in science, variable stars are named according to a process that started a hundred years ago, when Friedrich Wilhelm August Argelander assumed that the few variables to be discovered in each constellation could simply be given a letter according to the order of discovery. To avoid letters already used to name certain stars, Argelander began by calling the first variable to be discovered in any constellation by the letter R, the second S, and so on until Z.

After a while the magic figure of nine variables was reached and the system was expanded to include double letters beginning with RR, RS, and RT, through RZ, then SS to SZ, and TT through TZ until ZZ. But with time and active discoverers even this was not enough. The names continued with AA through AZ, BB through BZ and so on using every letter except J. Finally, the letters QZ were reached in one constellation of 334 variables, and the whole process was revamped so that the next star would be called V335. Thus, a bright nova discovered in Cygnus in 1975 was called V1500 Cygni, and Sagittarius has a star designated V2414.

But that's not all there is to variable star nomenclature. Variables have two names, one of which we've just explained. The other name, known as the "AAVSO" or "Harvard designation," is simply the coordinates of the star in compressed form. Thus, SS Cygni is also known as 213843, since its right ascension is 21h 38m and its declination +43°. (Negative declinations are underlined or italicized.) Convenient? Well, sort of. The coordinates are for the epoch 1900, no longer used in any active star atlas (most use either 2000 or 1950). While these Harvard designations are necessary, they are no longer very precise as positional guides.

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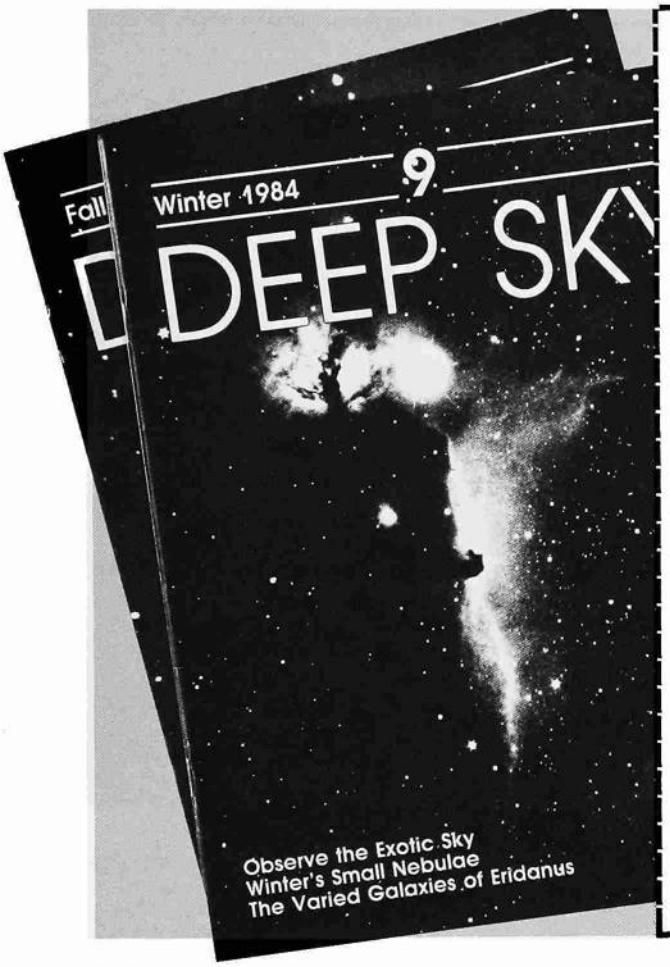

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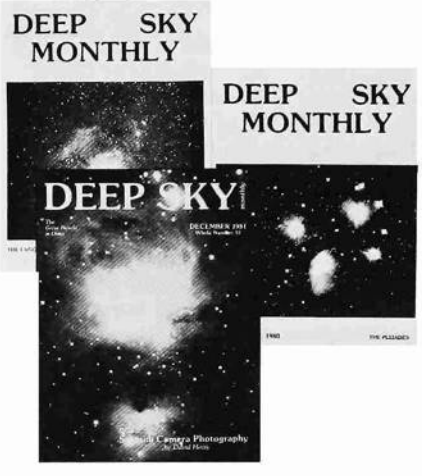

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Scanning the Literature

November 1984 — February 1985

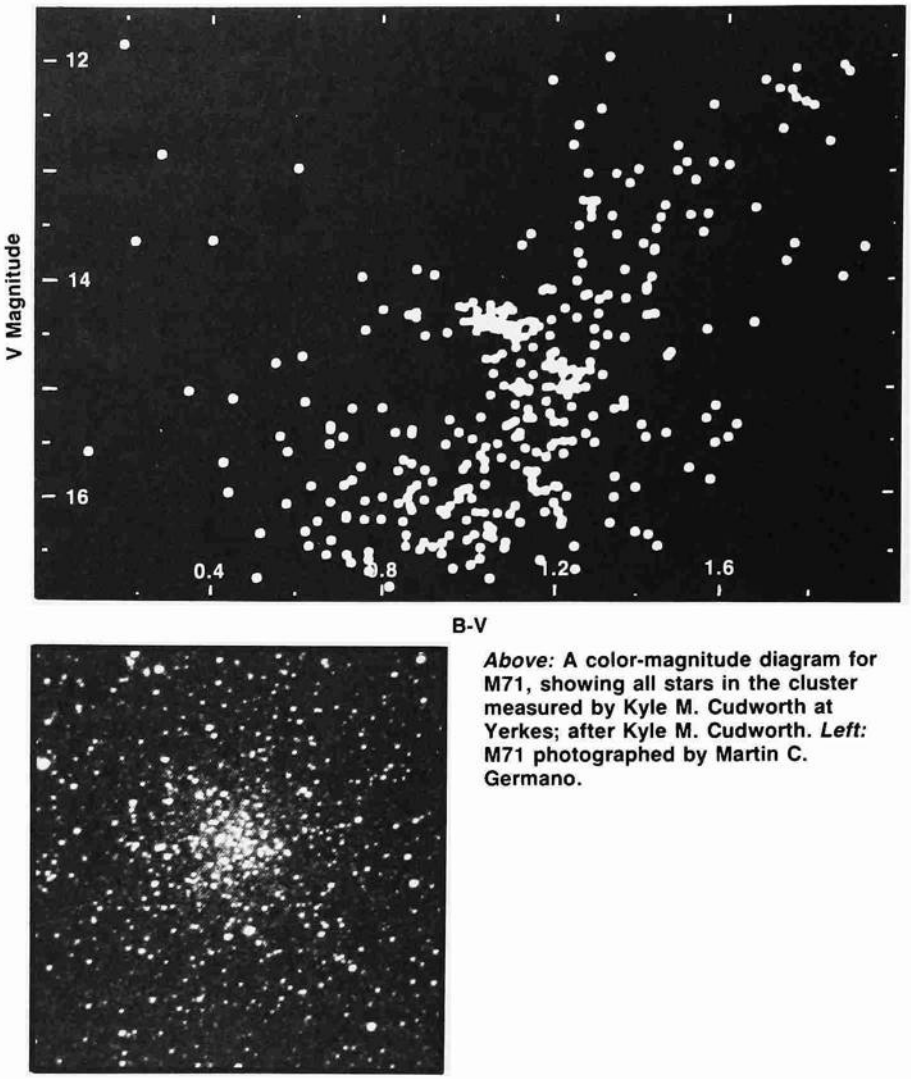
by Brian Skiff

The New Year's Day issue of *Astrophysical Journal (ApJ)* contains a complete explanation of the controversial connection between the galaxy NGC 4319 and the quasar Markarian 205, both in Draco ("The Nature of the Luminous Feature Between Markarian 205 and NGC 4319," Gerald Cecil and Alan Stockton, *ApJ* **288:**201, January 1). Cecil and Stockton applied sophisticated image-processing techniques to CCD images of the pair. The resulting photographs indeed show material around Markarian 205 and its faint stellar companion, as has been pointed out by Chip Arp and Jack Sulentic, champions of the galaxy-quasar link. Cecil and Stockton argue, however, that Markarian 205 seems to have no physical relationship with NGC 4319, and interpret the feature as the result of Markarian 205 colliding with its tiny companion — possibly an elliptical galaxy. In this scenario, all *three* objects are at the correct redshift distances: the luminous "connection" does not bridge the quasar to the foreground spiral NGC 4319. These objects have been discussed in *Deep Sky* several times (see issues 3, 8, and 9).

A new redshift survey involving two galaxy clusters in Hercules has been published by Stephen A. Gregory and Laird A. Thompson ("The A2197 and A2199 Galaxy Clusters," *ApJ* **286:**422, November 15). Gregory and Thompson's paper bring the total number of galaxies with redshifts in this region to 136. Abell 2199 is the nearest of the rich "cD" clusters, containing a single central supergiant galaxy (NGC 6166), and is thus of special interest.

The mean redshifts for the clusters are 9166 and 9360 kilometers per second for A2199 and A2197, respectively, implying a distance of approximately 120 megaparsecs (assuming 75 km/sec/Mpc). Their projected separation on the sky is only 2 Mpc. A map of the redshifts for the clusters suggests a "supercluster" bridge of galaxies between this "double cluster" and the Hercules cluster (A2141), which lies about 20° south and at nearly the same redshift velocity.

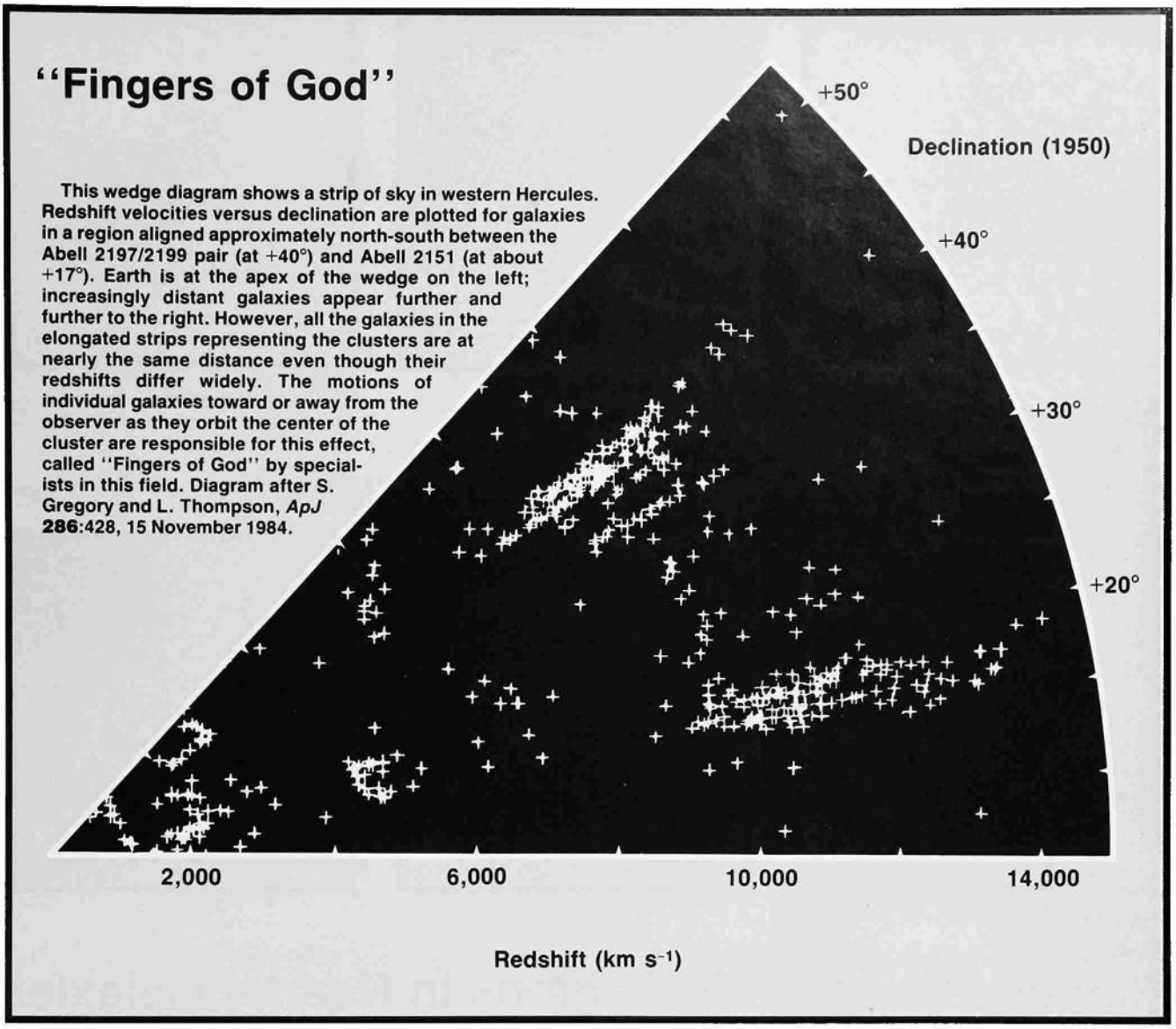
The authors summed existing photometry for A2199 galaxies to find an integrated magnitude of 10.1 for the cluster. They analyzed the mass necessary to keep each cluster gravitationally bound and found that 200 to 400 times more is required than is evident from the visible luminosity of the galaxies. This is fairly typical for galaxy clusters, but it implies there is much "missing mass" — which is really missing *brightness* — tied up in the component galaxies. Making the same calculation for the cluster pair, the mass-to-light ratio is less than 100; evidently, that missing mass is mostly in the cores of the clusters.



Above: **A color-magnitude diagram for M71, showing all stars in the cluster measured by Kyle M. Cudworth at Yerkes; after Kyle M. Cudworth.** ***Left:*** **M71 photographed by Martin C. Germano.**

Twice this column has provided information on early studies of globular clusters around the bright southern galaxy NGC 5128 (*Deep Sky* 1 and 7). Two new man *vs.* machine searches by the same group of Canadian astronomers extends our knowledge of these objects ("The NGC 5128 Globular Cluster System: Star Counts in U, V, and R," Gretchen L.H. Harris, James E. Hesser, Hugh C. Harris, and Patrick J. Curry, *ApJ* **287:**175, December 1; and "The NGC 5128 Globular Cluster System: A Complete Analysis of Images Using COSMOS," Hugh C. Harris, Gretchen L.H. Harris, James E. Hesser, and Harvey T. MacGillivray, *ApJ* **287:**185, December 1).

The first paper describes counts of stars (and stellar objects) on three prime-focus photographs made with the Cerro Tololo reflector. The photographs cover an area of sky extending 23′ from the center of the galaxy. The authors found an excess of 800 to 900 objects brighter than magnitude 22. Assuming the luminosity function (the relative number of objects per magnitude interval) for the globulars is the same as that for the Milky Way — and compensating for incompleteness — they found 1200 to 1900 possible clusters in the entire system. Whereas before 1980 no clusters were known,

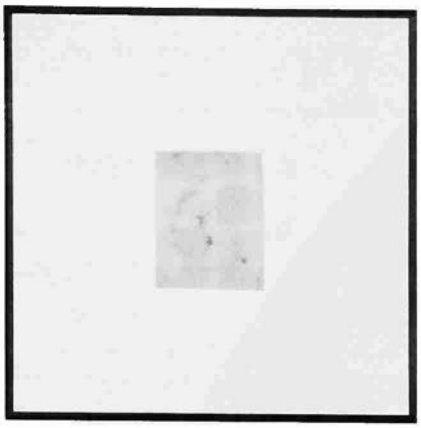

"Fingers of God"
This wedge diagram shows a strip of sky in western Hercules. Redshift velocities versus declination are plotted for galaxies in a region aligned approximately north-south between the Abell 2197/2199 pair (at +40°) and Abell 2151 (at about +17°). Earth is at the apex of the wedge on the left; increasingly distant galaxies appear further and further to the right. However, all the galaxies in the elongated strips representing the clusters are at nearly the same distance even though their redshifts differ widely. The motions of individual galaxies toward or away from the observer as they orbit the center of the cluster are responsible for this effect, called "Fingers of God" by specialists in this field. Diagram after S. Gregory and L. Thompson, ApJ 286:428, 15 November 1984.
+50°
Declination (1950)
+40°
+30°
+20°
2,000
6,000
10,000
14,000
Redshift (km s⁻¹)

the galaxy is now shown to have a small, but nearly normal, complement of globulars.

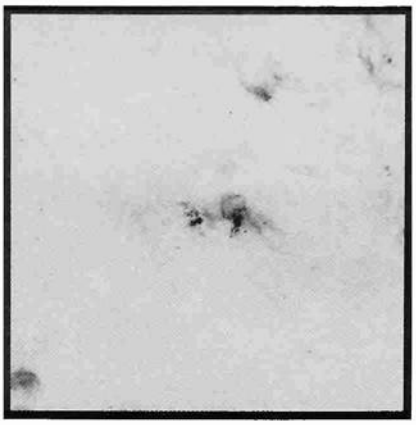
The second paper describes similar counts made by digitally scanning plates and attempts to sort out cluster candidates from stars and galaxies. The purpose here was to compare the thoroughness and reliability of visual "manual" counts with the hopefully more objective automated procedures. Over 7600 images brighter than 20th magnitude were measured. Neither procedure is an easy task nor especially preferable, as foreground stars and distant unresolved galaxies contaminate both samples. The automated search found several probable new bright clusters (V = 17 or 18), but the number of faint candidates picked up was similar in both cases.

Supernova hunters will be interested in an up-to-date reference list compiled by R. Barbon and associates ("A Revised Supernova Catalogue," *Astronomy and Astrophysics Supplements* **58**:735, December). This compendium provides essential data on 568 supernovae discovered from 1885 (S Andromedae — the first extragalactic supernova to be sighted) through the end of 1983. For convenience, tables are sorted both by right ascension of the parent galaxy and by date of occurrence. (This makes it easy to answer questions like: how many supernovae have occurred in M101? How many supernovae were recorded in 1975?) The distribution according to magnitude, supernova type, and morphological type of the parent galaxy are shown. Observers take note: at least half the supernovae occurred among Sb, Sbc, and Sc galaxies.

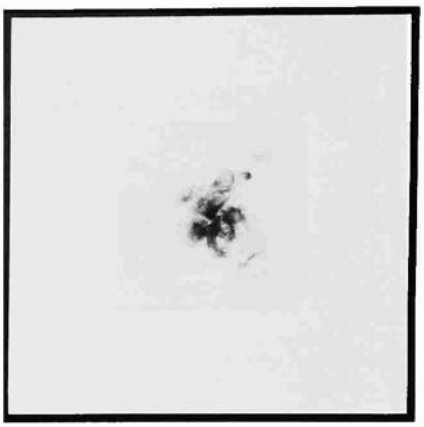
"*Giant HII regions have been applied extensively as tracers of chemical composition, star formation, and spiral structure in galaxies, and as extragalactic distance indicators, but in spite of this broad application little is known about the physical properties of the HII regions themselves.*" With this introduction, Robert Kennicutt begins one of several studies of these objects appearing in recent journals ("Structural Properties of Giant HII Regions in Nearby Galaxies," *ApJ* **287**:116, December 1). He uses emission-line maps and existing radio continuum data to derive densities, masses, ionization requirements, and structural properties of a sample of galactic and nearby extragalactic nebulae. The Lagoon Nebula, the Rosette, NGC 3603, and the Eta (η) Carinae Nebula are among the observed Milky Way objects. An illuminating sequence of Hα photographs are presented, showing several nebulae at the same spiral scale. This sequence reveals the entire Orion complex to be a pipsqueak among nebulae — even among those in the Milky Way, which are generally smaller than many found in nearby late-type spirals like M101. Measuring 5 parsecs in diameter, M42 is only $1/100$ the size of giant HII regions in M33 and M101. Eta Carinae, at 200 parsecs across, is typical of objects outside the Galaxy. Giant emission regions over 500 parsecs across may exist in the Milky



M42 in Orion
(Milky Way)

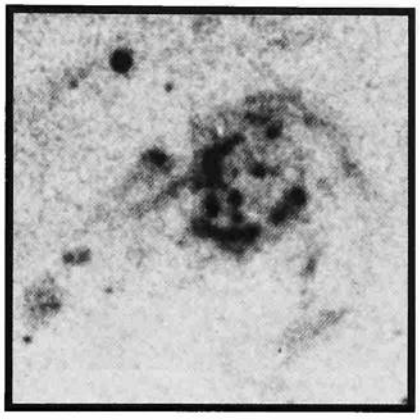


NGC 3603 in Centaurus
(Milky Way)

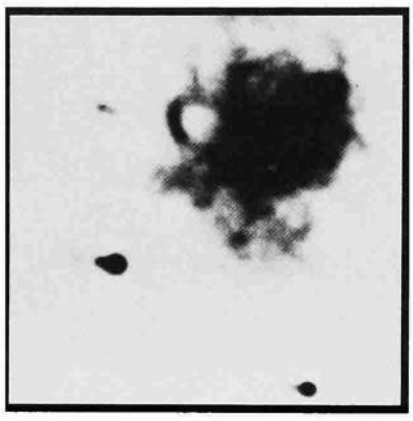


NGC 3372 in Carina
(Milky Way)

Pellett 550 in Andromeda
(M31)



NGC 604 in Triangulum
(M33)



Henize N70
(LMC)

Relative Sizes of HII Regions in Nearby Galaxies

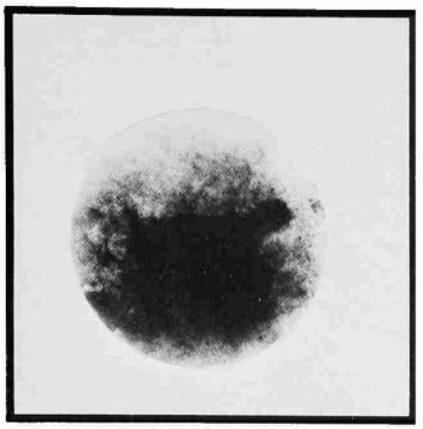
Way, Kennicutt concludes, but are obscured by interstellar absorption and (in the radio part of the spectrum) by confusion with other sources in the line of sight. Kennicutt finds that giant HII regions are a heterogeneous bunch, but within any one galaxy exhibit less varied properties, suggesting that galaxy-wide conditions in the interstellar medium are important for determining their structure.

A seemingly contradictory conclusion is reached by Deidre A. Hunter and John S. Gallagher III in "Structural Similarities Among Nearby Giant HII Regions" (*Astronomical Journal (AJ)* **90:**80, January). They found a "common morphological pattern" among the giant HII regions: "*a group of young stars are compact star clusters nestled in an arc of intense Hα emission from ionized gas. From this arc, less dense ionized gas produces lower surface brightness Hα emission which spreads out like a cosmic analog to the alluvial fans from certain types of mountains.*" This arc or nearly ring-shaped form is visible in NGC 604 (in the galaxy M33), and in nebulae within galaxies NGC 2366 and M101. The latter nebulae are visible in large amateur instruments, especially with the aid of a nebula filter. The authors also present data for a few individual stars in giant HII regions, such as Wolf-Rayet stars in NGC 604 which shine at magnitude 16 to 17. Hunter and Gallagher find common structural properties in galaxies of widely differing masses and luminosities, suggesting that star formation is a local process not strictly dependent on the type of galaxy it occurs in.

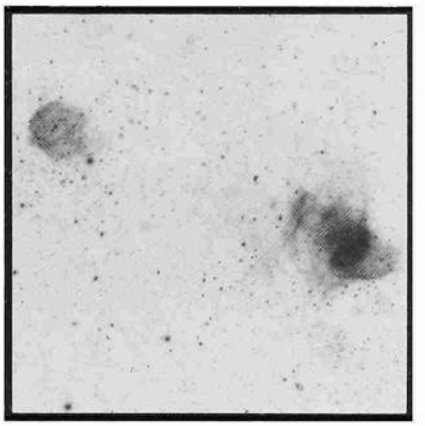
More detailed analysis of these objects is given in a huge paper by Marshall L. McCall, Paul M. Rybski, and Gregory A. Shields ("The Chemistry of Galaxies. I. The Nature of Giant Extragalactic HII Regions," *Astrophysical Journal Supplement Series* **57:**1, January). The astronomers made spectrophotometric observations of 99 HII regions in 20 spiral and irregular galaxies. They found a great range of excitation among the observed nebulae. The lowest excitation regions are dominated by the light from underlying associations containing hot O and B-type stars. The nebular emission is composed mostly of hydrogen lines, with those of heavier elements — "metals" — being relatively weak. At the other end of the scale, a high excitation nebula overpowers the fluorescing stars: their spectra show emission in the forbidden oxygen lines several times stronger than the hydrogen lines. In fact the strength of the oxygen emission relative to hydrogen was found to be the most important determinant of an HII region's spectrum, serving also as a predictor of the other metals' intensities.

One clear conclusion from all these studies is that the giant HII regions are not different from normal "Orion Nebulae" — they are merely the very largest of their class.

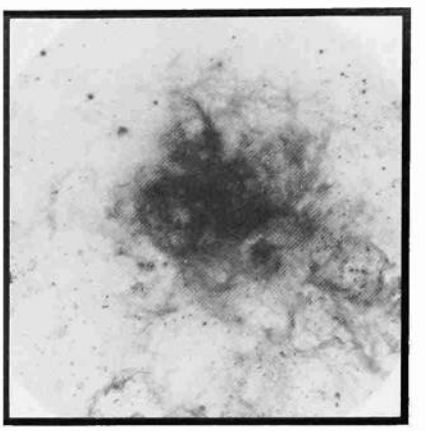
The metal content of two open clusters is the subject of Carol A. Christian's work "Abundance Estimates



NGC 3372 (long exposure)
(Milky Way)

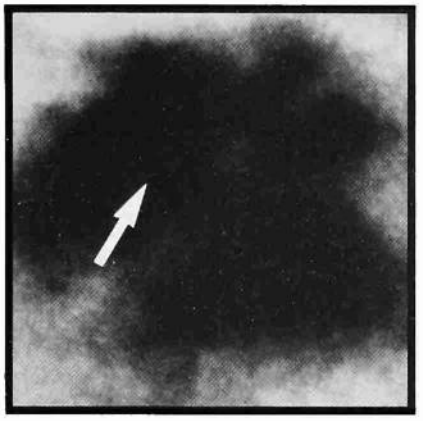


Henize N66 and N76
(SMC)

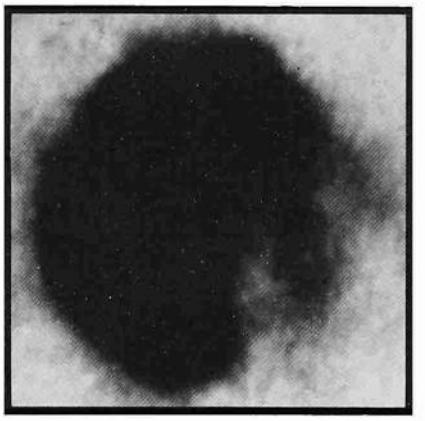


NGC 2070 in Doradus
(LMC)

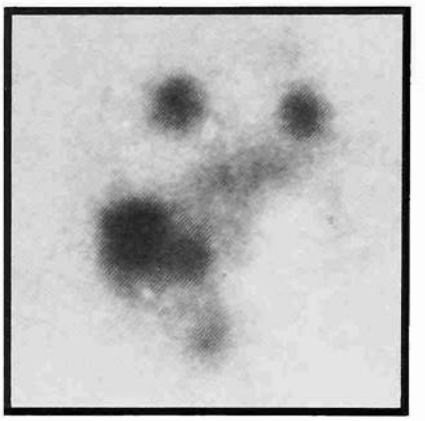
M82A (arrowed)
(M82)



NGC 5471 in Ursa Major
(M101)



NGC 5471 (short exposure)
(M101)



From our vantage point inside the Milky Way, the Orion Nebula (M42) is one of the most impressive showpieces of the sky. With its diameter of 5 parsecs, however, M42 (far upper left) is a mere midget among HII regions. The two images at lower right show NGC 5471, an emission nebula in M101 which measures some 800 parsecs across. Photographs courtesy Robert C. Kennicutt, Jr.

for the Distant Anticenter Clusters King 8 and Be 19" (*ApJ* **286**:552, November 15). She made spectrophotometric observations of suspected members of these clusters located toward the edge of the Milky Way's disk in Auriga. Her initial studies of the clusters (including UBV photometry and photos) were published in *AJ* **85**:700 (for Berkeley 19) and *ApJ* **246**:827 (for King 8). The latter is an interesting cluster in large amateur instruments. Analysis of the spectrophotometry yielded spectral types and chemical abundance estimates for the observed stars. The results confirm the distances and reddenings of both clusters as determined from the earlier work. The age of King 8 is about 800 million years — roughly equivalent to the Hyades. Berkeley 19 is thought to be a few billion years old, and present studies do not contradict this. Both clusters are poor in metals relative to the Sun. Christian summarizes her interest in these clusters this way: "*Distant open clusters represent practical tools for probing the galactic disk, particularly in the anticenter where the outermost parts of the galactic plane can be surveyed . . . . Many of these [older star clusters] remain as witnesses to a poorly understood epoch in the history of the galactic disk.*"

A bright cluster in Cassiopeia receives thorough study in a paper by Mario Predreros, Barry F. Madore, and Wendy Freedman ("Photographic Photometry of the Open Cluster NGC 7790, *ApJ* **286**:563, November 15). The cluster contains three Cepheid variables — CF Cas and CE Cas, which contains two such stars 2.3″ apart. The authors measured Canada/France/Hawaii 3.6-meter telescope plates calibrated with existing photoelectric work adjusted to a homogeneous system. The cluster was found to be 8.2′ in diameter from star counts. Magnitudes and colors are given for about 300 stars to 19th magnitude within this area, which are identified on a photograph. The new data indicate a distance of about 2.9 kiloparsecs. The cluster is also dimmed nearly two magnitudes by interstellar absorption.

One of the very few proper motion analyses of globular clusters has been done by Kyle M. Cudworth ("Photometry, Proper Motions, and Membership in the Globular Cluster M71," *AJ* **90**:65, January). Photographic photometry and proper motions are given for over 350 stars brighter than V magnitude 16. The photometry was calibrated with a new photoelectric sequence in the cluster, while the astrometry is based on measures of plates dating back to 1901 taken with the Yerkes, Lick, and Allegheny refractors (the big ones!). The color-magnitude diagram of probable and possible members shows a stubby, red horizontal branch (at V magnitude 14.3) identical to that of 47 Tucanae in the southern hemisphere, generally considered to be among the most metal-rich globulars. For M71, the tip of the giant branch reaches V magnitude 12 to 12.5; most of these luminous cluster members are somewhat variable.

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Distorted Galaxy NGC 3718

Kitt Peak National Observatory photograph